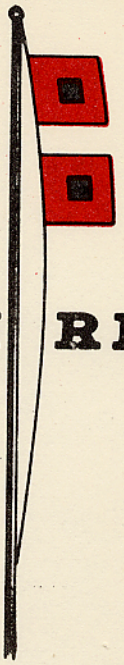
HURRICANE SURVEY

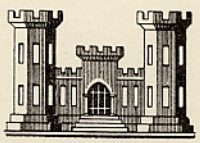


INTERIM REPORT

STAMFORD

CONNECTICUT

APPENDICES



U.S. Army Engineer Division, New England
Corps of Engineers
Boston, Mass.

8 APRIL 1958

ARMY-NED-BOSTON

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PLATES (Cont'd)

GLOSSARY

HURRICANE SURGE: the mass of water causing an increase in elevation of the water surface above predicted astronomical tide at the time of a hurricane; it includes wind setup; sometimes the maximum increase in elevation is referred to as the surge.

HURRICANE TIDE: the rise and fall of the water surface during a hurricane, exclusive of wave action.

KNOT: a velocity equal to one nautical mile (6080.2 ft.) per hour (about 1.15 statute miles per hour).

OVERTOPPING: that portion of the wave runup which goes over the top of a protective structure.

PONDING: the storage of water behind a dike or wall from local runoff and/or overtopping by waves.

POOL BUILDUP: the increase in elevation of water surface behind a structure due to runoff and/or overtopping by waves.

RUNUP: the rush of water up the face of a structure on the breaking of a wave. The height of runup is measured from the stillwater level.

SIGNIFICANT WAVE: a statistical term denoting waves with the average height and period of one-third highest waves of a given wave train.

SPRING TIDE: a tide that occurs at or near the time of new and full moon and which rises highest and falls lowest from the mean level

STILLWATER LEVEL: the elevation of the water surface if all wave action were to cease.

STORM SURGE: same as "hurricane surge."

WAVE HEIGHT: the vertical distance between the crest and preceding trough.

WAVE TRAIN: a series of waves from the same direction.

WIND SETUP: the vertical rise in the stillwater level on the leeward side of a body of water caused by wind stresses on the surface of the water.

APPENDIX A

GEOLOGY

APPENDIX A

GEOLOGY

PHYSIOGRAPHY

A-1. Stamford Harbor lies on the seaboard lowland of the New England physiographic province, at the confluence of the Rippowam River and Long Island Sound, in western Connecticut. Outer Stamford Harbor, wide and rock-studded, is bounded by Peck Point on the west and Shippan Point on the east. Additional exposure to the Sound is afforded Stamford by Westcott Cove, a broad, shallow embayment northeast of Shippan Point which narrowly misses connection with the East Branch; hence, Shippan Point, a peninsula, is almost an island under normal conditions. During times of high tidal flooding, the Point becomes an island. The business center of Stamford is of low relief and elevation, averaging under 20 feet msl, while elevations of 50 to 100 feet msl are attained in almost all inland directions within one-mile radius, except for the Rippowam River valley which attains an elevation of 50 feet msl about two miles north of the business center.

SUBSURFACE INVESTIGATIONS

A-2. Subsurface investigations, made by the New England Division, Corps of Engineers during 1956 and 1957, in conjunction with this survey, consisted of 45 drive-sample borings, 9 auger borings, 2 test pits, and 21 harbor probings. Supplemental information was available in the form of foundation boring records for the city's incinerator on the East Branch and the power plant of the Hartford Electric Light Company (formerly Connecticut Power Company) on the West Branch. Thirty-five drive-sample borings, 9 auger borings, and 2 test pits were made to determine foundation conditions for various dike alignments on land, and 6 drive-sample borings were made to determine foundation conditions in the harbor. In addition, 4 drive-sample borings and 21 probings were made in the harbor to determine excavation conditions for dredging of the bypass channel and the channel widening, and to establish the character of the East Branch as a potential borrow source. Subsurface explorations were supplemented with general field reconnaissance to determine surficial controlling features and the availability of borrow. Locations and graphic logs for all explorations are shown on Plates A-1 through A-5.

FOUNDATION CONDITIONS - EAST BRANCH PROTECTION

A-3. OVERBURDEN

Explorations for the East Branch disclosed no valley of great depth. A shallow valley exists under the Branch containing 20 to 30 feet of overburden except in the area of the dredged channel where the overburden is about 10 feet thick. The center of the bedrock depression is about 100 feet east of the centerline of the channel. The water on either side of the 12-foot (mlw) channel is shoal, much of the bottom being exposed as mud flats at low tide. A blanket of silt up to 8 feet thick, largely organic, covers the entire water crossing, except for the channel at the barrier site in Plan "E". Below the silt is a 10-to-30-foot thickness of varying compact, occasionally gravelly, silty sand and sandy silts. Between these deposits and bedrock is sandy till ranging in thickness from approximately 8 feet to zero feet at the center of the valley where the bedrock is overlain directly by gravelly silty sand.

A-4. BEDROCK

Bedrock, a biotic-gneiss, is moderately fresh and somewhat fractured in the vicinity of the gate structure, occurring variably between elevations of 25 and 30 feet below mean sea level in that area, deepening to about minus 32 feet under the east bank, and shoaling to about minus 20 feet under the west bank.

BYPASS AND CHANNEL WIDENING

A-5. Borings and probings in the proposed temporary bypass channel, west of the 12-foot channel in the East Branch, revealed no bedrock above grade. It is probable that small hummocks of bedrock will have to be levelled in a few places, but it is not expected that large quantities of rock excavation will be required. The only special condition anticipated in dredging the bypass channel is the probability of having to use a dipper dredge, owing to the existence of a few feet of till above grade in the southern portion. The area of proposed channel widening, on the east side of the 12-foot channel, appears equally favorable from an excavation standpoint, with probably a few relatively small areas of till and/or rock involved.

Much of both areas consists of compact gravel. Any difficulties involved in removing this will be considerably balanced by the fact that a 2-foot to 10-foot variable cover of easily removed silt exists in both areas.

FOUNDATION CONDITIONS - WEST BRANCH PROTECTION

A-6. DIKES AND WALLS

The entire West Branch protection traverses fill that is largely sand, gravel, fly-ash, and junk, or a mixture of these materials. The fill generally extends to about mean sea level, or a little below, owing to settlement of the fill in natural marsh deposits. The latter, however, are only a few feet thick, overlying firmer silts, sands and gravels. A 15-foot thickness of soft organic materials at the west abutment of the pumping station at the small inlet west of Dyke Park, may continue or thicken westward to the West Branch.

A-7. PUMPING STATION

A boring to determine foundation conditions at the pumping station had to be offset south of the proposed centerline in order to clear a large sunken barge. The materials encountered were compact gravels and sands beneath 4 feet of organic silt. Below the granular materials, which are about 25 feet thick, is a sandy glacial till about 5 feet thick. Beneath the sandy till is firmer, although sandy, till. At the east bank, sandy till lies 10 feet below the surface; at the west bank, the material, in order of depth, consists of 5 feet of fly ash, 5 feet of fly ash with peat, and another 5 feet of organic silt with peat, resting on compact silty, sandy gravel.

FOUNDATION CONDITIONS - WESTCOTT COVE PROTECTION

A-8. The materials surrounding Westcott Cove are variably silty sands and sandy silts, with occasional shallow deposits of peat. Much of the area has been built up with hydraulic fill, including a recent addition consisting of sands and, in part, organic silts. The western end of the dike alignment, south of Iroquois Road near West Beach, is on a dump containing up to 20 feet of cellophane scrap.

AVAILABILITY OF CONSTRUCTION MATERIALS

A-9. EARTH BORROW

It is anticipated that dredged materials from the bypass channel and channel widening will account for a major part of the dike material requirements. These materials are predominantly coarse-grained pervious; thus substantial finer materials are required and may be obtained by sand dredging in

Westcott Cove, at least for the eastern range of dikes. It probably will be necessary to resort exclusively to the use of such dredged materials. or to barging sand from Long Island, in view of the acute earthen borrow shortage in the Stamford vicinity. True impervious natural materials are not readily available; however, a good grade of uniformly fine fly ash, such as that placed in the vicinity of the Hartford Electric Light Company property and Dyke Park, might qualify as a suitable impervious material for incorporation within the sand cores of the dike sections. Concrete aggregates are available locally from commercial sources.

A-10. ROCK BORROW

There are no active quarries within the general area of Stamford that are capable of producing suitable dimension stone for use in construction of the dikes and barrier. It has been assumed that stone will be obtained from major commercial sources with facilities for wide distribution. It is doubtful that a local quarrying operation could be undertaken that could compete with established commercial sources.

CONCLUSIONS AND RECOMMENDATIONS

A-11. The greatest problem appears to be the shortage of earthen borrow in the Stamford vicinity. Dredged or barged-in materials, largely sand, may have to be used, and the resulting seepage through embankments tolerated, in view of the anticipated short stand of high water. It is recommended that a general borrow sampling survey be made in outer Stamford Harbor and in Westcott Cove during the final design stage of the project.

Advanced foundation studies for barriers, dikes and walls should include detailed exploration and tests for shear strength, compressibility and permeability for both foundation and borrow materials. The main barrier across the East Branch is a relatively long and high embankment. There remain underlying silt deposits, even after assuming complete displacement of the organic silt harbor blanket, whose characteristics have not been determined fully; furthermore, the exact nature of the barrier fill is not known. A conservative section, therefore, having 1 on 2.5 rock-faced slopes is indicated pending further exploration and laboratory tests. The East Branch water crossing is favorable with regard to rock elevation and character under the proposed gate structure, and the absence of any valley of sufficient depth which could provide soft spots resulting in major displacement or settlement. Additional borings will be necessary to determine

in detail the rock surface under the gate structure, conditions for driving the piling of the cofferdam, and to adjust for any changes in alignment that might be made prior to construction.

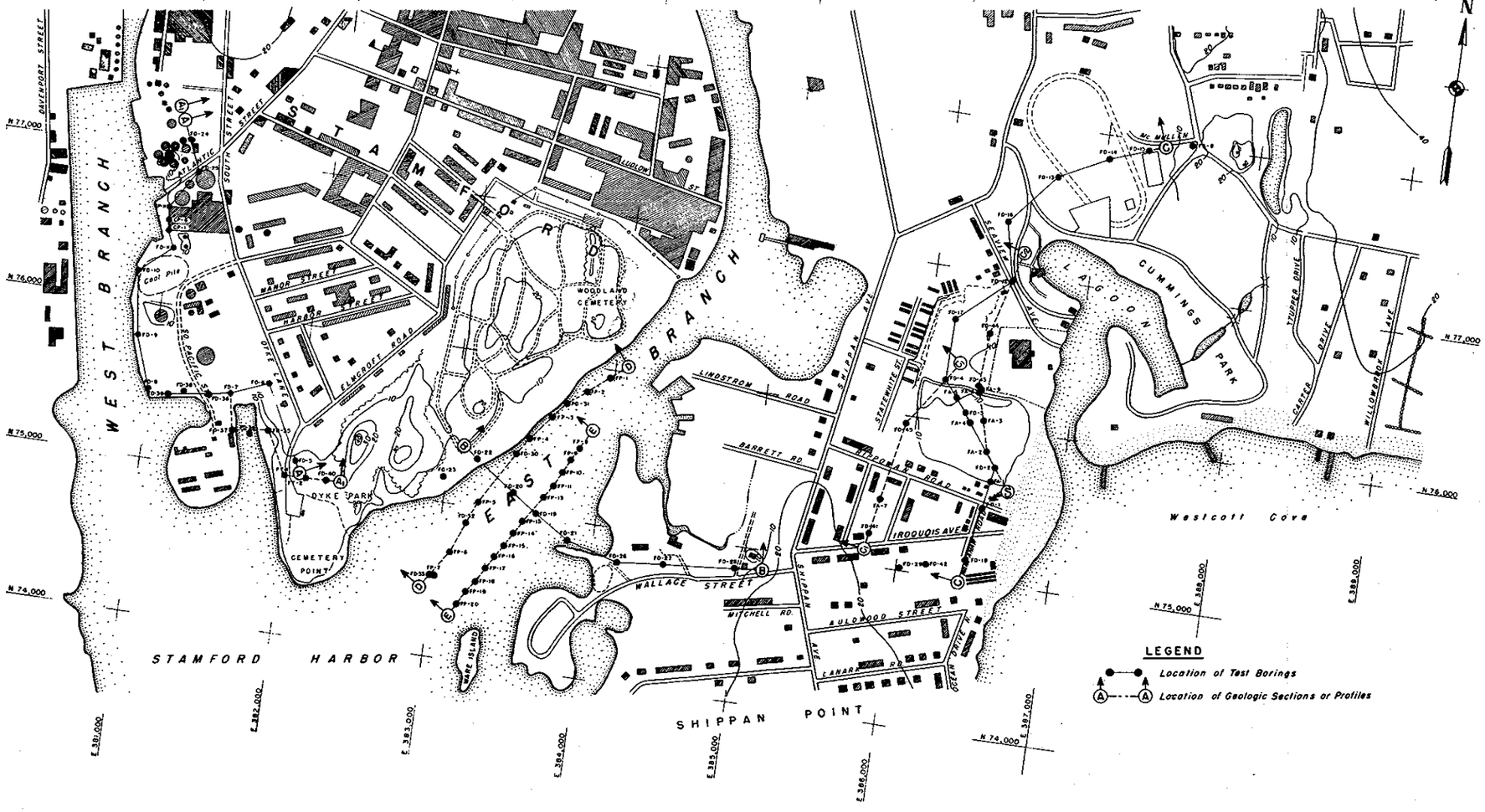
The South End pump station foundation is satisfactory, inasmuch as the structure has been designed to rest on piles. A detailed exploration of the area should be made at the time of final design to determine whether the structure can be placed directly on the firm gravel indicated by one of the borings in this vicinity. Poor conditions under the barrier west of the pumping station prompted designation of 1 on 2 slopes, with light rip-rap specified on the landward slope.

The short length of earth dike along the east side of the lower West Branch should not be affected adversely by a proposed shift southward of the 45-foot high coal pile. If the shift occurs prior to construction of the dike, it can be expected to preconsolidate the area and help stabilize this section. The area should be watched, however. Foundation conditions vary from good granular materials to fly-ash, peat, and refuse requiring excavation. Earth dikes under 8 feet in height, or higher where good foundations prevail, have seaward slopes specified 1 on 1.5, rock-faced, and landward slopes 1 on 2, seeded. Higher dikes have been designed with seaward slopes of 1 on 2, rock-faced. If washed dredged fill is used, an impervious zone may have to be incorporated where seepage is critical. However, light loading and short duration of exposure may render such measures unnecessary. Conventional T-wall design has been specified, since no special problems other than the necessity of removing pockets of unsuitable fill material are evident. The proximity of slopes to the ship channel in the southerly portion is not expected to cause any difficulties, because an old, presumably well-established rip-rap wall already lines the bank. The main problem in the West Branch is the character of the materials under the dike alignment across the entrance of the small cove on the east bank and then extending east to the pumping station. Expansion plans of the power company call for the filling of this cove which is within their property limits. It is possible that a significant displacement or settlement condition exists in this area, despite favorable indications from borings to the north. Borings to the east indicate a 15-foot depth of undesirable saturated materials. If the better condition exists, it is possible that improvement dredging in the West Branch adjacent to the site may provide valuable construction materials. The soft organic area west of the pump station site is recognized to constitute a problem which will require detailed exploration during the time of final design. This may conceivably lead to a modification of alignment or design of structure at that time. For the present, the slopes have been flattened as noted above.

The materials in the Cummings Park area are not to be considered to create any special problem except for the aforementioned dump and undesirable organic silt stratum under the stoplog structure at the public beach - all of which should be removed - and a recent hydraulic spoil area north of Rippowam Road. Much of the latter (see Plate A-4) is good material, but the spoil area is an active borrow source and its future condition cannot be ascertained. The present dike section assumes that the area will remain reasonably intact.

CORPS OF ENGINEERS

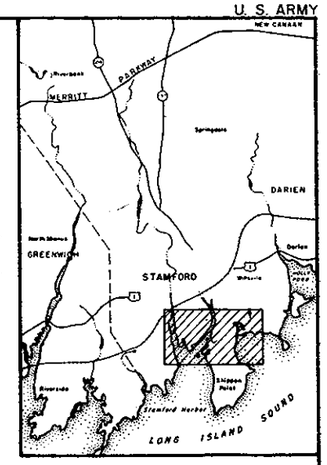
U. S. ARMY



GENERAL LOCATION PLAN

SCALE IN FEET

300' 0 300' 600'



GENERAL VICINITY MAP

LEGEND

Location of Test Borings

Location of Geologic Sections or Profiles

NOTE:

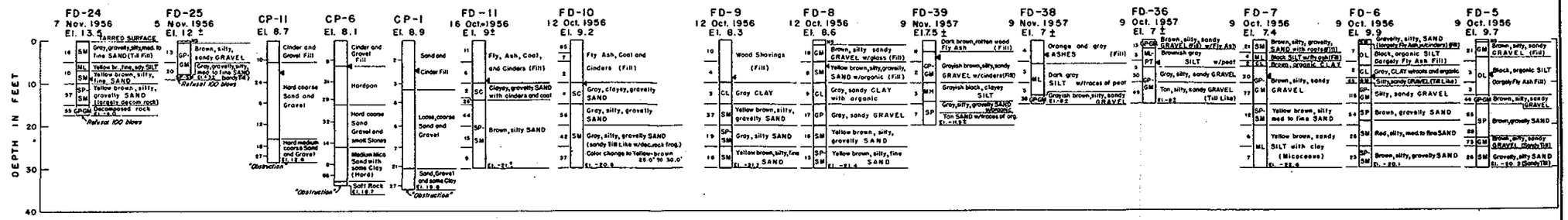
Coordinates are on the Lambert Grid System for the State of Connecticut.

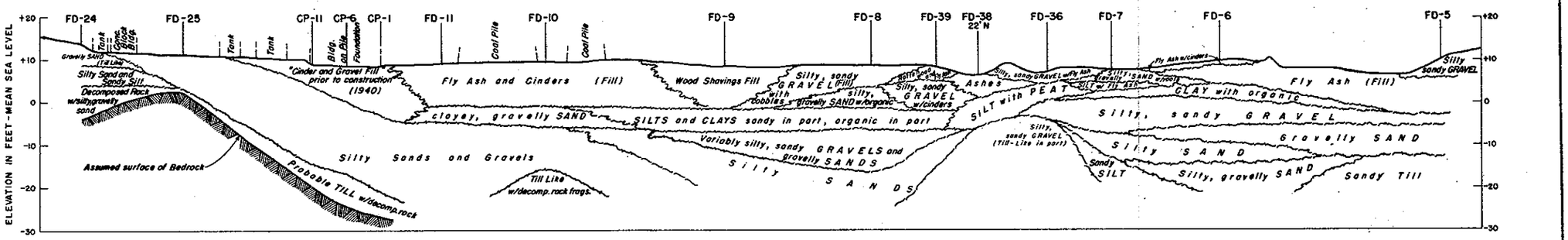
U. S. ARMY ENGINEER DIVISION NEW ENGLAND
CORPS OF ENGINEERS
BOSTON, MASS.

PREPARED BY C. WARD	HURRICANE SURVEY
DRAWN BY R. MARSWELL	STAMFORD
CHECKED BY W. SUMLEY	CONNECTICUT
K.C. Ludl — CHIEF, NED LABORATORIES	GEOLOGY
CHIEF, HURRICANE UNIT	
SUBMITTED BY: CHIEF, PLANS & REPTS BRANCH	
Approved — CHIEF ENGINEERING DIV	APPROVED: LT COL C E ASST TO DIVISION ENGINEER
	DATE APRIL 1958
TO ACCOMPANY REPORT DATED 8 APRIL 1958	AS SHOWN; DRAWING NUMBER ST-2-1000; 1 of 5

PLATE A-1

CORPS OF ENGINEERS U.S. ARMY



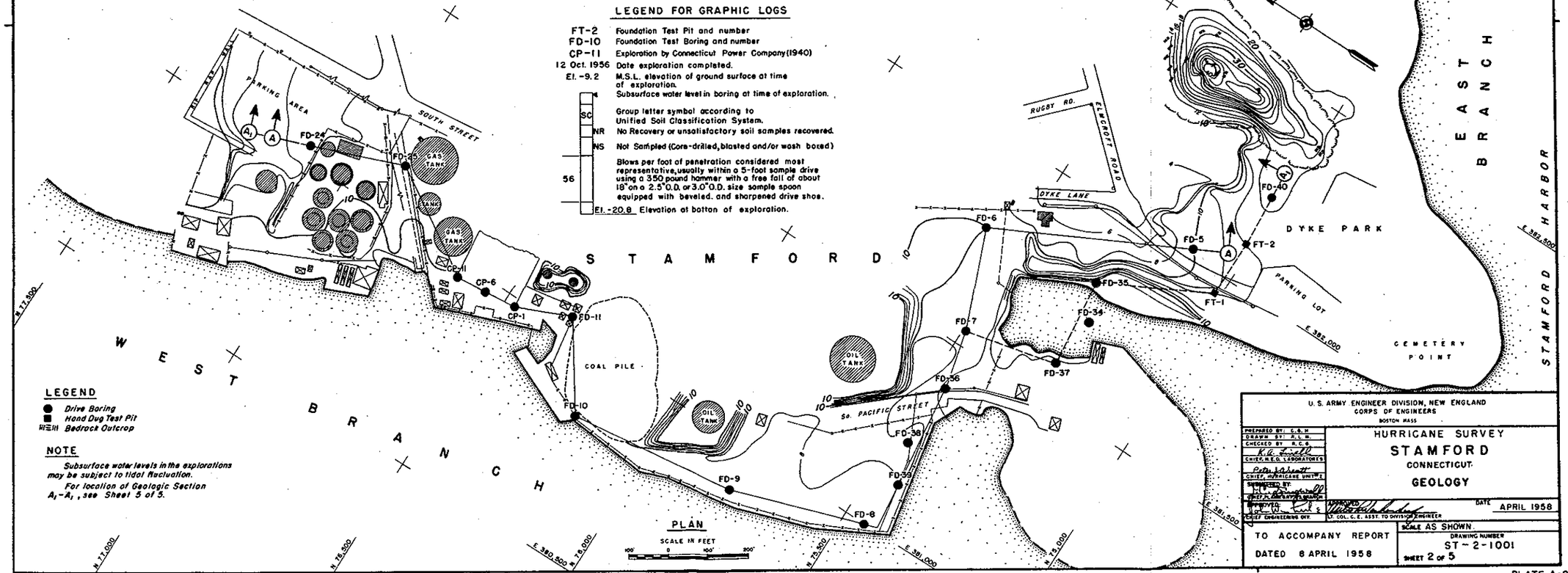


GEOLOGIC SECTION A-A

Horizontal Scale 100 0 50 100 200 FT.

LEGEND FOR GRAPHIC LOGS

FT-2 Foundation Test Pit and number
FD-10 Foundation Test Boring and number
CP-11 Exploration by Connecticut Power Company (1940)
12 Oct. 1956 Date exploration completed.
El. -9.2 M.S.L. elevation of ground surface at time of exploration.
Subsurface water level in boring at time of exploration.
SC Group letter symbol according to Unified Soil Classification System.
NR No Recovery or unsatisfactory soil samples recovered.
NS Not Sampled (Core-drilled, blasted and/or wash bored)
56 Blows per foot of penetration considered most representative, usually within a 5-foot sample drive using a 350 pound hammer with a free fall of about 18" on a 2.5" O.D. or 3.0" O.D. size sample spoon equipped with beveled and sharpened drive shoe.
El. -20.8 Elevation at bottom of exploration.



LEGEND

- Drive Boring
- Hand Dug Test Pit
- Bedrock Outcrop

NOTE

Subsurface water levels in the explorations may be subject to tidal fluctuation.

For location of Geologic Section A1-A1, see Sheet 5 of 5.

PLAN SCALE IN FEET 0 100 200

U. S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
BOSTON, MASS.

HURRICANE SURVEY
STAMFORD
CONNECTICUT
GEOLOGY

PREPARED BY: C.G.H.
DRAWN BY: R.L.G.
CHECKED BY: R.C.G.
CHIEF, M.E.G. LABORATORIES
SUBMITTED BY:
CHIEF, ENGINEERING BRANCH
APPROVED BY:
CHIEF ENGINEERING DIV.
APPROVED
Lt. COL. C.E. ASST. TO DIVISION ENGINEER
DATE APRIL 1958

TO ACCOMPANY REPORT
DATED 8 APRIL 1958

SCALE AS SHOWN
DRAWING NUMBER ST-2-1001
SHEET 2 OF 5

PLATE A-2

CORPS OF ENGINEERS

U.S. ARMY

FD-23
7 Nov. 1956
El. 7.6

FD-22
2 Nov. 1956
El. +6.6

FD-20
26 Oct. 1956
El. - 6.1

FD-19
25 Oct. 1956
El. - 5.2

FD-21
30 Oct. 1956
El. - 0.9

FD-26
6 Nov. 1956
El. +6.3

FD-27
7 Nov. 1956
El. +7.8

FD-28
8 Nov. 1956
El. +6.6

DEPTH IN FEET

LEGEND FOR GRAPHIC LOGS

FD-19 — Foundation Test Boring and number
25 Oct. 1956 — Date exploration completed.
El. - 5.2 — M.S.L. elevation of ground or river bottom at time of exploration.
Subsurface water level in boring at time of exploration.
SM — Group letter symbol according to Unified Soil Classification System.
NR — No Recovery or unsatisfactory soil samples recovered.
NS — Not Sampled (Core-drilled, blasted and/or wash bored)
10 — Blows per foot of penetration considered most representative, usually within a 5-foot sample drive using a 350 pound hammer with a free fall of about 18" on a 2.5" O.D. size sample spoon equipped with beveled and sharpened drive shoe.
* — Blow count not recorded or not considered representative.
Cobbles or boulders (Core-drilled)
Cobbles or boulders continous or nested. (Core-drilled and/or blasted and chopped)
El. -25.3 — Elevation of bedrock surface.
Rock core recovery 0 - 25 %
Rock core recovery 25 - 50 %
Rock core recovery 50 - 75 %
Rock core recovery 75 - 90 %
Rock core recovery 90 - 100 %
El. -33.8 — Elevation at bottom of exploration.

FD-22 FD-20 FD-19 FD-21 FD-26 FD-27 FD-28

ELEVATION IN FEET - MEAN SEA LEVEL

Gravel Fill; PEAT; Organic SILT; Silty SAND gravelly in part; Sandy Silty Sand; Sandy SILT; Gravelly silty SAND; Ship Channel; Mean Sea Level; Organic SILT; SILT; Silty SAND gravelly in part; Silty, sandy GRAVEL; SAND; Sandy SILT; SAND; SILT; Assumed Bedrock Surface; Sandy SILT; Sandy, silty GRAVEL; PEAT; Salt Marsh; Sandy TILL; Silty, fine SAND; Clayey Sandy Gravelly Sandy CLAY; Sandy TILL

GEOLOGIC SECTION B-B

Horizontal Scale 100 0 50 100 200 FT.

FD-33 4 Sept. 1957 El. -2.3 | FD-7 27 Aug. 1957 El. -2.4 25R | FD-6 28 Aug. 1957 El. -2.7 | FD-32 29 Aug. 1957 El. -1.2 | FP-5 28 Aug. 1957 El. -0.7 | FD-30 27 Aug. 1957 El. +0.2 | FP-4 28 Aug. 1957 El. -0.0 | FP-3 28 Aug. 1957 El. -0.9 | FD-31 28 Aug. 1957 El. +2.5 | FP-2 28 Aug. 1957 El. -1.4 | FP-1 28 Aug. 1957 El. -2.7

ELEVATION IN FEET - M. S. L.

Line of Probing Refusal

LOG PROFILE D-D

Horizontal Scale 1" = 100'

FP-20 23 Aug. 57 El. -8.5 | FP-19 23 Aug. 57 El. -10.0 | FP-18 23 Aug. 57 El. -9.6 | FP-17 23 Aug. 57 El. -9.9 | FP-16 26 Aug. 57 El. -5.9 | FP-15 26 Aug. 57 El. -7.0 | FP-14 27 Aug. 57 El. -7.0 | FP-13 27 Aug. 57 El. -8.4 | FP-21 4 Sep. 57 El. -12.1 | FP-12 27 Aug. 57 El. -8.0 | FP-11 27 Aug. 57 El. -11.5 | FP-10 27 Aug. 57 El. -12.2 | FP-9 27 Aug. 57 El. -5.6 | FP-8 27 Aug. 57 El. -12.3

ELEVATION IN FEET - M.S.L.

Line of Probing Refusal

PROBING PROFILE E-E

Horizontal Scale 100 0 50 100 200 FT.

WOODLAND CEMETERY

STAMFORD

EAST BRANCH

Proposed by Jess Channel (Approx.)

Existing Channel Limit (Approx.)

Existing Channel Widening (Approx.)

Proposed Channel Widening (Approx.)

High Water (Approx.)

℄ Barrier

DYKE PARK

SPOIL PILE

SHIPPAN POINT

SHIPPAN AVE.

STAMFORD HARBOR

FD-1 FD-2 FD-3 FD-4 FD-5 FD-6 FD-7 FD-8 FD-9 FD-10 FD-11 FD-12 FD-13 FD-14 FD-15 FD-16 FD-17 FD-18 FD-19 FD-20 FD-21 FD-22 FD-23 FD-26 FD-27 FD-28 FD-30 FD-31 FD-32 FD-33

N 75,500 N 75,000 N 74,500

E 382,500 E 383,000 E 383,500 E 384,000 E 384,500 E 385,000

PLAN

SCALE IN FEET 100' 0 100' 200'

LEGEND:

Test Boring or Probing
Bedrock Outcrop

NOTE:

Subsurface water levels in the explorations may be subject to tidal fluctuation.

NOTES:

FP-1 Foundation Probing and number. Probing "refusals" refer to relative resistance offered to drill rods after boring been jetted through soft overlying harbor sediments.

U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
BOSTON, MASS.

PREPARED BY: G.S.K.
DRAWN BY: R.L.B.
CHECKED BY: R.C.D.
CHIEF, MED LABORATORIES
CHIEF, HURRICANE UNIT NO 2
APPROVED BY
CHIEF ENGINEERING DIV.

HURRICANE SURVEY
STAMFORD
CONNECTICUT
GEOLOGY

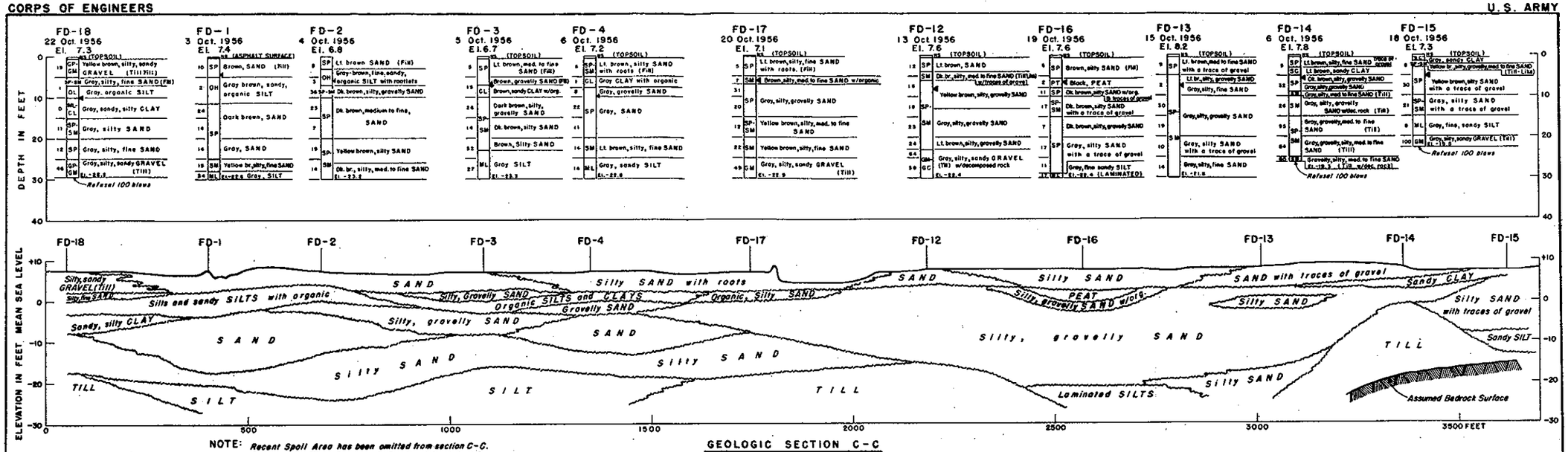
DATE APRIL 1958
APPROVED
LT. COL. C.E. ASST. TO DIVISION ENGINEER

TO ACCOMPANY REPORT
DATED 8 APRIL 1958

SCALE AS SHOWN
DRAWING NUMBER
ST-2-1002
SHEET 3 OF 5

PLATE A-3

CORPS OF ENGINEERS U.S. ARMY



NOTE: *Recent Spoil Area has been omitted from section C-C. Refer to Profiles C_1-C_1 and C_2-C_2, Sheet 5 of 5.*

GEOLOGIC SECTION C-C
Horizontal Scale As Shown

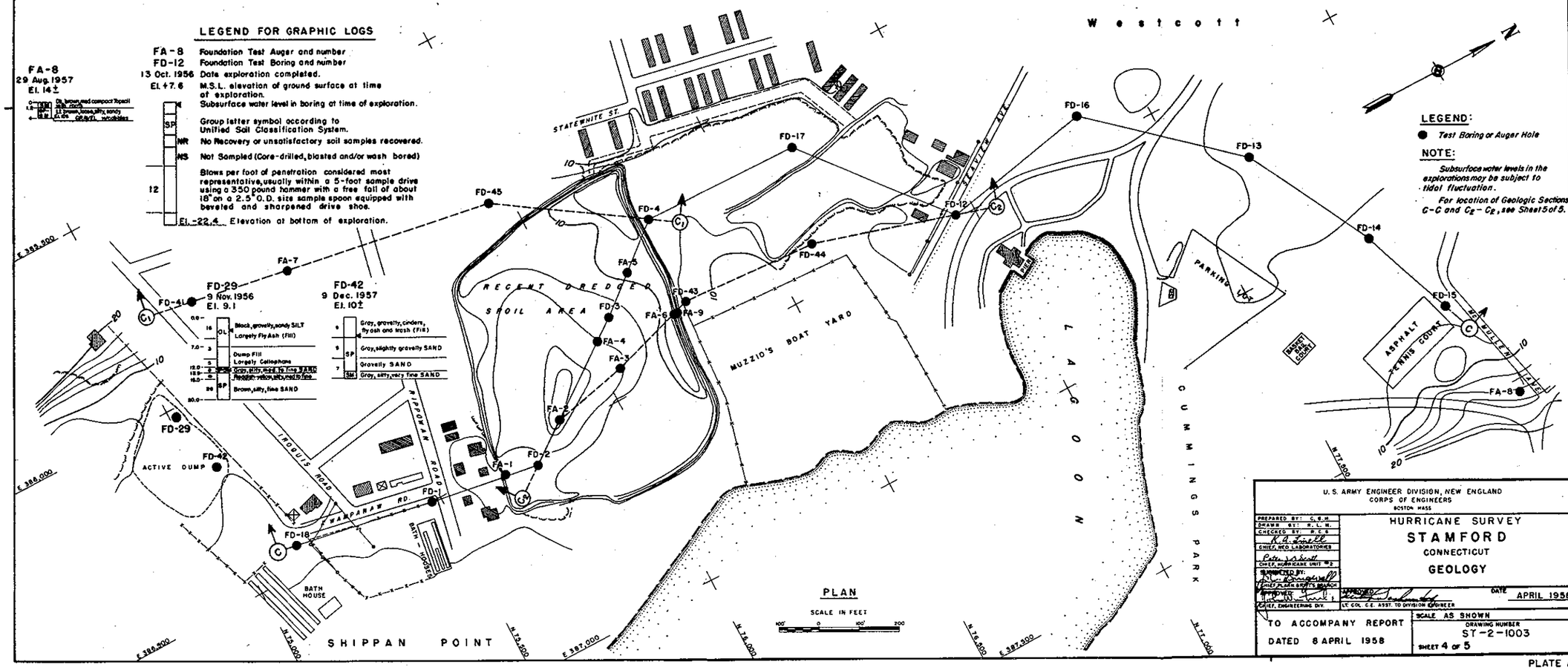
LEGEND FOR GRAPHIC LOGS

FA-8 Foundation Test Auger and number
FD-12 Foundation Test Boring and number
13 Oct. 1956 Date exploration completed.
El. +7.6 M.S.L. elevation of ground surface at time of exploration.
Subsurface water level in boring at time of exploration.
SP Group letter symbol according to Unified Soil Classification System.
NR No Recovery or unsatisfactory soil samples recovered.
NS Not Sampled (Core-drilled, blasted and/or wash bored)
12 Blows per foot of penetration considered most representative, usually within a 5-foot sample drive using a 350 pound hammer with a free fall of about 18" on a 2.5" O.D. size sample spoon equipped with beveled and sharpened drive shoe.
El. -22.4 Elevation at bottom of exploration.

FA-8
29 Aug. 1957
El. 14±

FD-29
9 Nov. 1956
El. 9.1
Black, gravelly, sandy SILT
Largely Fly Ash (Fill)
Dump Fill
Largely Cellophane
Gray, silty, mod. to fine SAND
Peaty in places
Brown, silty, fine SAND

FD-42
9 Dec. 1957
El. 10±
Gray, gravelly, cinders, fly ash and wash (Fill)
Gray, slightly gravelly SAND
Gravelly SAND
Gray, silty, very fine SAND



PLAN
SCALE IN FEET
100' 0 100' 200'

LEGEND:
● *Test Boring or Auger Hole*

NOTE:
Subsurface water levels in the explorations may be subject to tidal fluctuation.
For location of Geologic Sections C-C and C_2-C_2, see Sheet 5 of 5.

U. S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
BOSTON MASS.

PREPARED BY: C.R.H.
DRAWN BY: R.L.W.
CHECKED BY: R.C.S.
CHIEF, NED LABORATORIES
CHIEF, HURRICANE UNIT
SUBMITTED BY:
CHIEF, PLANS & SPEC'S BRANCH
APPROVED:
CHIEF, ENGINEERING DIV.

HURRICANE SURVEY
STAMFORD
CONNECTICUT
GEOLOGY

DATE APRIL 1958
LT. COL. C.E. ASST. TO DIVISION ENGINEER

TO ACCOMPANY REPORT
DATED 8 APRIL 1958

SCALE AS SHOWN
DRAWING NUMBER
NY-2-1003
SHEET 4 OF 5

PLATE A-4

LEGEND FOR GRAPHIC LOGS

FT-2 Foundation Test Pit
FA-6 Foundation Hand Auger Boring
FD-2 Foundation Test Boring
4 Oct. 1957 Date exploration completed
El. 6.8 MSL elevation of ground surface at time of exploration

Subsurface water level in boring at time of exploration

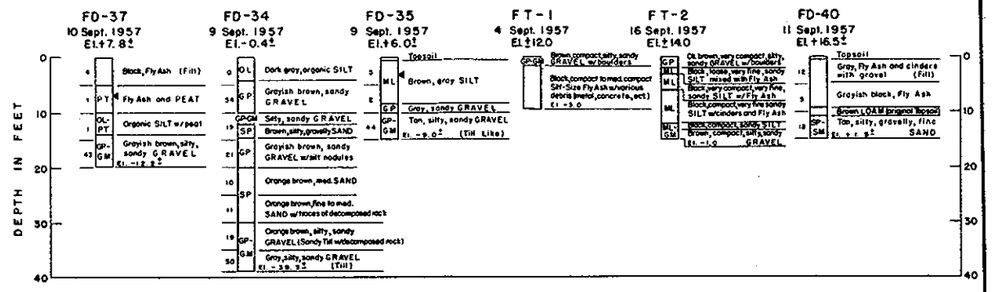
SP Group letter symbol according to Unified Soil Classification System

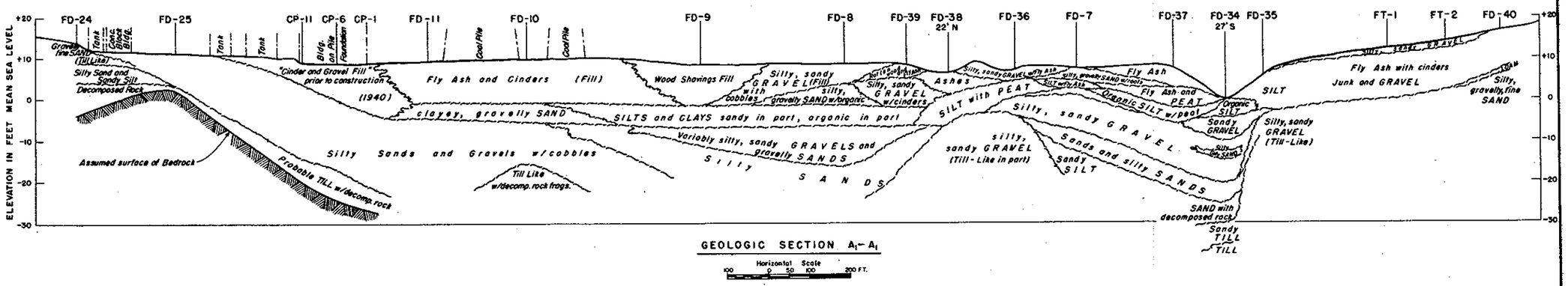
NR No Recovery or unsatisfactory soil samples recovered

NS Not Sampled (Core-drilled, blasted and/or wash bored)

19 Blows per foot of penetration considered most representative, usually within a 5-foot sample drive using a 350 pound hammer with a free fall of about 18" on a 2.5" O.D. size sample spoon equipped with beveled and sharpened drive shoe.

El. -23.2 Elevation at bottom of exploration





GEOLOGIC SECTION A_1-A_1

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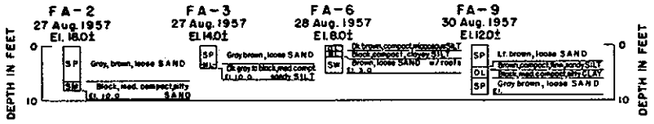

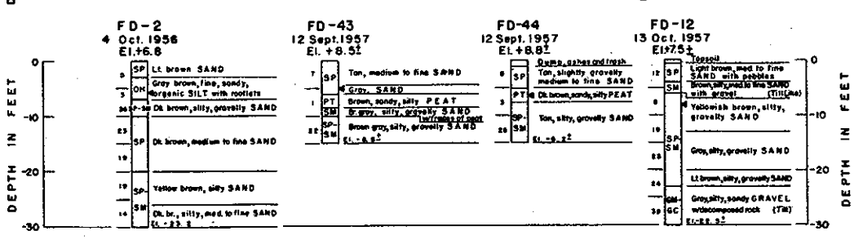

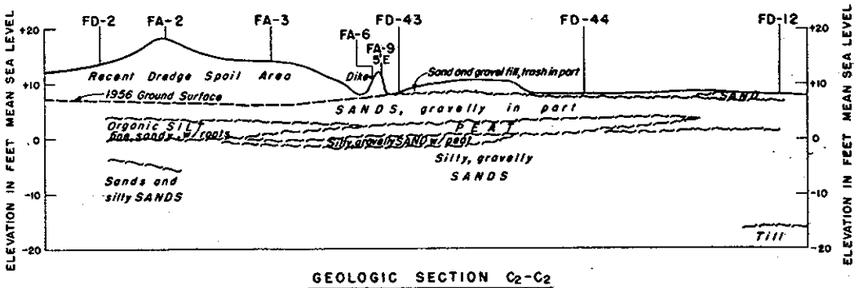

GEOLOGIC SECTION C_2-C_2

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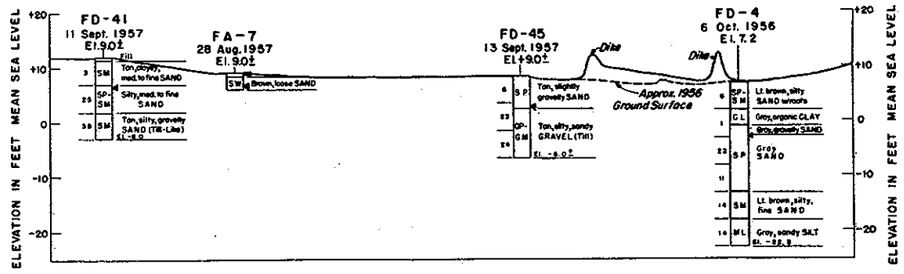


LOG PROFILE C_1-C_1

Horizontal Scale 100 0 50 100 200 FT.

NOTE:

Subsurface water levels in the explorations may be subject to tidal fluctuation.

U. S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
BOSTON, MASS.

HURRICANE SURVEY
STAMFORD
CONNECTICUT
GEOLOGY

PREPARED BY: C.B.H.
DRAWN BY: H.L.W.
CHECKED BY: R.C.T.
CHIEF, MED LABORATORIES
CHIEF, HURRICANE Unit No 2
SUBMITTED BY:
CHIEF, PLANS & SURVEYS BRANCH
APPROVED:
CHIEF ENGINEERING DIV.
APPROVED:
LT-COL. C.E. ASST. TO DIVISION ENGINEER
DATE APRIL 1958
SCALE AS SHOWN
TO ACCOMPANY REPORT
DATED 8 APRIL 1958
DRAWING NUMBER ST-2-1004
SHEET 5 OF 5

PLATE A-5

APPENDIX B

HYDROLOGY AND HYDRAULICS

APPENDIX B

HYDROLOGY AND HYDRAULICS

INTRODUCTION

B-1. This appendix presents data to supplement the sections of the main report relating to the subjects of hydrology and hydraulics. It includes a summary of temperature and precipitation data to amplify the section of the report on "Climatology", and data on hurricane wind velocities, rainfall values, and barometric pressures to augment report material on the history and frequency of hurricanes. A determination of tidal flood levels and design storm tide, and detailed analyses of wave height, runup, overtopping, ponding, and current velocities are also included in this appendix.

HYDROLOGY

B-2. TEMPERATURE AND PRECIPITATION

Records of temperature and precipitation at the U.S. Weather Bureau station at Stamford, Connecticut, are available since 1950, but due to the relatively short period of record and the fact that the station was relocated in December 1955, the data are not considered representative. However, there are records of temperature and precipitation covering a period of over 60 years at the U.S. Weather Bureau station at Norwalk, Connecticut, 8 miles east of Stamford. Monthly means and extremes of temperature for 61 years of record at Norwalk, and mean, maximum, and minimum monthly precipitation data for 64 years of record, are summarized in Tables B-1 and B-2.

B-3. DRAINAGE AREAS

The drainage areas of the West and the East Branches, in and above the protected area of Plan "E", are 172 acres and 1211 acres, respectively. The latter figure includes 54 acres of water surface in the East Branch above the barrier crossing. The drainage area behind the Westcott Cove dike is 113 acres. These three areas that contribute runoff to ponding areas behind the protective works are shown on Plate B-1.

B-4. STORM RAINFALL

The greatest rainfalls associated with hurricanes in New England are those recorded for "Connie and "Diane" in August 1955. Hurricane "Connie", 11-15 August, caused rainfall varying from about four to six inches over southern New England and ended a period of drought. A week

later, on 17-20 August, Hurricane "Diane" brought rainfall of 16 to 20 inches over Connecticut and Massachusetts. The rainfall at Stamford in Hurricane "Connie" equalled 4.2 inches in 24 hours and a total of 8.8 inches during the 3-day period of 12-14 August. The recorded rainfall at Stamford and at nearby localities, in a number of recent hurricanes and one severe storm, are tabulated in Table B-3 on page B-4.

The storm of 14-17 October 1955, not a hurricane, caused five successive high tides at Stamford which reached elevations of nearly 8 feet msl, approximately 4 feet above mean high water. This storm produced record rainfall in Stamford totalling 13.29inches in 73 hours. More than one-half of this rainfall, or 7.86 inches, fell in a 12-hour period, including a one-hour intensity of 2.07 inches and one half-hour intensity of 1.26 inches. With recorded rainfall at Stamford limited to daily measurements, distribution was derived by mass curve analysis (see Plate B-2) based on hourly values at Brentwood, Long Island, and Candlewood Lake, Connecticut. The accumulated Stamford precipitation was then rearranged to form the pattern of rainfall shown in the hyetograph at the top of Plates B-3, B-4, and B-5.

TABLE B-1

MONTHLY TEMPERATURES AND EXTREMES (1893-1953)

Norwalk, Connecticut

	Degrees Fahrenheit				Degrees Fahrenheit		
Month	Mean	Maximum	Minimum	Month	Mean	Maximum	Minimum
Jan.	27.7	70	-22(1)	July	72.2	102	42
Feb.	27.7	69	-20	Aug.	70.1	104(2)	34
Mar.	36.5	87	- 6	Sep.	63.5	102	28
Apr.	47.2	92	9	Oct.	52.7	90	16
May	58.5	96	24	Nov.	41.3	83	-4
June	67.3	100	34	Dec.	30.5	71	-16
				Annual	49.6		

Note: Table does not reflect data for years 1954 and 1955 for which only incomplete records are available.

(1) 5 Jan. 1904 and 28 Jan. 1935.
(2) 26 Aug. 1948.

TABLE B-2

MONTHLY PRECIPITATION (1892-1955)

Norwalk, Connecticut

	Inches				Inches		
Month	Mean	Maximum	Minimum	Month	Mean	Maximum	Minimum
Jan.	3.59	7.35	0.54	July	4.06	11.81	0.65
Feb.	3.41	7.46	.49	Aug.	4.92	15.80	.37
Mar.	4.25	12.42	.23	Sep.	3.90	15.64	.23
Apr.	3.74	8.60	.77	Oct.	3.67	17.23(2)	.31
May	4.09	10.78	.07(1)	Nov.	3.77	8.86	.95
June	3.40	10.54	.14	Dec.	3.76	8.58	.85
				Annual	46.55	62.95(3)	33.67(4)

(1) May 1903
(2) Oct. 1955
(3) 1955
(4) 1935

TABLE B-3

HURRICANE AND OTHER STORM RAINFALL

Stamford, Connecticut and Nearby Locations

Accumulated Rainfall in Inches

Hurricane	Stamford, Conn. Max. (1) 24-hr.	Stamford, Conn. Total	Norwalk, Conn. Max. (1) 24-hr.	Norwalk, Conn. Total	Bridgeport, Conn. Max. 24-hr.	Bridgeport, Conn. Total	New Haven, Conn. Max. 24-hr.	New Haven, Conn. Total	Mineola, L. I. Max. 24-hr.	Mineola, L. I. Total
Sept. 1938	-	-	-	10.7	5.1	11.9	6.4	11.6	4.4	11.0
Sept. 1944	-	-	4.65	8.5	5.8	10.7	4.0	8.5	4.8	11.1
Aug. 1954 (Carol)	2.3	2.6	2.7	3.1	1.6	1.7	2.75	2.75	2.5	3.25
Sept. 1954 (Edna)	3.7	4.0	4.4	4.4	3.5	3.5	5.55	5.55	4.5	5.35
Aug. 1955 (Connie)	4.2	8.8	3.6	8.2	3.9	5.3	3.2	3.6	8.2	12.8
Aug. 1955 (Diane	3.2	4.7	4.1	5.2	1.9	3.0	3.2	4.3	1.1	1.5
Oct. 1955	9.6	13.29	8.2	13.0	5.8	7.15	3.2	5.9	2.3	4.0

(1) Non-recording station - values based on daily readings.

B-5. HURRICANE WINDS

The most reliable data on experienced hurricane wind velocities in New England begin with the September 1938 hurricane. The maximum velocity in New England during this storm was a recorded gust of 186 mph at the Blue Hill Observatory in Milton, Massachusetts, where a sustained 5-minute wind of 121 mph was also recorded. At other locations in southern New England, sustained 5-minute velocities ranging from 38 to 87 mph were experienced.

During the hurricane of 14 September 1944, a maximum gust of 104 mph was registered at Chatham, Massachusetts, near the east end of Cape Cod. Sustained 5-minute velocities ranging from 33 to 82 mph were recorded at a number of locations between New York City and Block Island, Rhode Island, during the same hurricane. At Westerly, Rhode Island, the calm during the passing of the "eye" of the storm was clearly noted.

In southern New England, during Hurricane "Carol" (31 August 1954), gusts of 125 and 130 mph were experienced at Blue Hill, Massachusetts, and Block Island, Rhode Island, respectively. Sustained 1-minute velocities ranging from 38 to 93 mph were registered.

Recorded wind velocities at locations in southern New England and New York City for the three great hurricanes of 1938, 1944 and 1954 are given in Table B-4, on the following page.

The wind data in Table B-4 are for historical hurricanes that passed to the east of Stamford and caused high surges to enter the east entrance of Long Island Sound. Greater winds would be experienced at Stamford in the event of a hurricane moving along a track to the west of Stamford, over the general vicinity of New York City. A maximum wind of 95 mph from the south can be anticipated at Stamford if a hypothetical hurricane, equivalent of the 1944 hurricane off Cape Hatteras, was to move north along a path usfficiently west of Stamford to produce maximum winds at Stamford. See paragraph B-10, "Design Storm Tide Derivation."

B-6. HURRICANE BAROMETRIC PRESSURES

The center of "eye" of the 1938 hurricane entered Connecticut about 5 miles west of New Haven (30 miles northeast of Stamford) at about 3:30 P.M., EST, on 21 September and then proceeded northwesterly at a rate of from 50 to 60 mph. The lowest pressure registered during the passage of this storm was 28.04 inches at Hartford, Conn.

TABLE B-4

WIND VELOCITIES

New England Hurricanes of 1938, 1944 and 1954

Location	Velocity in Miles Per Hour: Sustained 5-Min.	Sustained 1-Min.	Maximum Gust	Direction
Hurricane of 21 September 1938				
New York, N. Y.	70	-	80	NW
New Haven, Conn.	38	-	46	NE
Hartford, Conn.	46	-	59	NE
Block Island, R. I.	82	-	91	SE
Milton, Mass. (Blue Hill Observatory)	121	-	185	S
Hurricane of 14 September 1944				
New York, N. Y.	81	99	-	N
New Haven, Conn.	33	38	65	N & NE
Hartford, Conn.	50	62	109 (est)	N
Point Judith, R.I.	85 (est)	90 (est)	-	SSE
Block Island, R. I.	82	88	-	SE
Milton, Mass. (Blue Hill Observatory)	67	77	-	-
Hurricane of 31 August 1954				
New York, N. Y.	-	-	61	NW
Bridgeport, Conn.	-	-	60	-
Hartford, Conn.	-	56	64	NE
New Haven, Conn.	-	38	65	N
Block Island, R. I.	-	93	130	SE
Milton, Mass. (Blue Hill Observatory)	-	93	125	SE

In the hurricane of 14 September 1944, the "eye" of the storm passed inland between Charlestown and Point Judith on the south coast of Rhode Island (100 miles east of Stamford) at about 10:20 P.M., EST. It then continued in a northeasterly direction veering out to sea at Boston, Massachusetts. The minimum recorded barometric pressure in southern New England during this storm was 28.31 inches at Joint Judith.

The center of Hurricane "Carol" (31 August 1954) crossed the south shore of Connecticut in the vicinity of New London (75 miles east of Stamford) at about 10:30 A.M., EST, and then followed a general northwesterly path across New England. The minimum barometric pressures in New England upon the occasion of this hurricane were 28.20 inches at Storrs, Connecticut, (90 miles northeast of Stamford) and 28.26 inches at New London.

The minimum pressures recorded at a number of New England locations and New York City during these three great hurricanes of the past 20 years are given in Table B-5.

TABLE B-5

MINIMUM BAROMETRIC PRESSURES

New England Hurricanes of 1938, 1944, and 1954

Location	Time (EST)	Barometer (INCHES)
Hurricane of 21 September 1938		
New York, N. Y.	2:45 P.M.	28.72
New Haven, Conn.	3:30 P.M.	28.11
Hartford, Conn.	4:17 P.M.	28.04
Block Island, R. I.	3:05 P.M.	28.66
Milton, Mass. (Blue Hill Observatory)	-	29.01
Hurricane of 14 September 1944		
New York, N. Y.	7:15 P.M.	29.08
New Haven, Conn.	8:50 P.M.	28.86
Hartford, Conn.	9:50 P.M.	28.94
Point Judith, R. I.	10.20 P.M.	28.31
Block Island, R. I.	10.09 P.M.	28.34
Milton, Mass. (Blue Hill Observatory)	-	28.62
Hurricane of 31 August 1954		
New York, N. Y.	-	29.6
Bridgeport, Conn.	-	29.9
New Haven, Conn.	9:30 A.M.	28.8
Storrs, Conn.	-	28.2
New London, Conn.	-	28.3
Block Island, R. I.	-	28.5
Milton, Mass. (Blue Hill Observatory)	-	29.9

B-7. RUNOFF.

Runoff studies for the three drainage areas above the protective works in Plan "E" (See Plate B-1 and paragraph B-3) were predicated on the storm of 14-17 October 1955. Discharge hydrographs for these three areas, draining into the West Branch, East Branch, and Westcott Cove, together with the 12-hour hyetograph upon which they are used, are shown on Plates B-3, B-4, and B-5. The computed hydrographs are based on synthetic unit graph methods of analysis in which the 12-hour rainfall was applied to the respective one-half hour unit hydrograph, after deducting infiltration losses of 0.1 inch per hour for the areas draining to the East and West Branches and 0.4 inch per hour for the Westcott Cove Area. The characteristics of the Westcott Cove area, with grassy, rolling terrain, are less conducive to high runoff than the urban areas adjacent to the East and West Branches. The West Branch (South End) hydrograph has a peak of 264 cfs. The total volume of runoff is 96 acre feet, equivalent to 6.7 inches over the drainage area. See Plate B-3. The inflow hydrograph for the East Branch has a peak of 1275 cfs and a volume of 670 acre-feet or 6.7 inches of runoff from the drainage area. See Plate B-4. The inflow hydrograph for the Westcott Cove area has a peak of 139 cfs and a volume of 35 acre feet, or 3.76 inches of runoff from the drainage area. See Plate B-5.

B-8. HURRICANE OR STORM-TIDE FLOOD LEVELS

The heights of tidal flooding experienced at a number of locations in Stamford and other Connecticut coastal areas during Hurricane "Carol" (1954) were obtained during the course of damage-survey work in the field. The elevations of these flood levels, referred to mean sea level, were then determined by a field level party. This information was supplemented by material of high water levels collected by this office after the September 1938 hurricane. Based on this information, profiles have been prepared of the 1938 and 1954 tidal-flood elevations between Willets Point, New York, at the western end of Long Island Sound, and Wareham, Massachusetts, at the eastern end of Buzzards Bay. A map and profile for the coastline between Willets Point, New York, and the town line between Westport and Fairfield, Connecticut, have been prepared. See Plates B-6 and B-7. At Stamford, approximately Mile 20 on the profile, general levels of 11.0 feet msl in 1938 and 10.3 feet msl in 1954 are indicated. The tidal elevation-frequency data, shown in Table B-6, incorporates all information and procedures used in deriving the elevation-frequency curve shown on Plate B-8.

B-9. PONDING

The volumes of runoff that would pond behind the West Branch protection, in the pool behind the East Branch barrier, and behind the Westcott Cove protection, in the event of recurring 1938, 1944, and 1954 hurricanes and a recurring October 1955 storm, are summarized in Table B-7. In determining the levels of ponding in the South End, in the area protected by the West Branch walls and dike, consideration

was given to the existing 10,000 gpm pumping station located at Pacific and Crosby Streets and to the proposed 40,000 gpm station in the protective works west of Dyke Park. At present, storm water from the existing station is conducted through an existing 24-inch (C.I.) force main, along Pacific to South Street, a distance of about 1,100 feet, then discharged by gravity to the West Branch through a line crossing the power company property. Under Plan "E", the existing line along Pacific Street would discharge into a new interceptor (42 inches in diameter along South Street and 54 inches in diameter along Dyke Lane) that would be installed between Atlantic Street and the storage pond of the proposed new pumping station. A total storm drainage of approximately 90 cfs would reach the proposed new pumping station through this interceptor.

The determination of the volume of fresh water that would accumulate behind the protective works during periods of heavy rainfall is predicated on closure of the navigation gate in the East Branch barrier and the conduits at the pumping station when the flood tide is at a stage of zero msl. The navigation gate would be opened, to permit discharge by gravity, when the falling tide reaches a stage equal to the level of ponding behind the barrier; the gates at the pumping station would open when the falling tide reached a stage of zero feet msl. Closure of lines under the Westcott Cove protection would occur when the tide is at or about 7 feet msl. This is approximately the stage at which backup through the lines would start to cause flooding behind the dike. Gravity discharge would also begin in the Westcott Cove-Cummings Park area when the tide falls below the level of ponding in this area. The gates in the East and West Branch protection would be closed for periods of 7 to 9.5 hours upon recurrence of the 1938, 1944, and 1954 hurricanes and the storm of October 1955. Ponding in the Westcott Cove area would be experienced for periods of two to three hours.

Only the October 1955 storm causes any ponding that results in damages. The ponding in this storm reaches an elevation of 5.1 feet msl behind the West Branch protection, 6.6 feet msl behind the East Branch barrier, and 7.5 feet msl behind the Westcott Cove dike, or stages that are 1.6, 0.3, and about 0.2 feet, respectively, above the stages where flood damage begins. The damages at these stages are small and, on an annual basis, negligible.

The peak levels of ponding caused by runoff equivalent to that experienced in recent important storms and hurricanes, as shown in Table B-7, have been determined from the area-capacity curves shown on Plates B-10, B-11, and B-12. These curves are based on U.S. Geological Survey maps supplemented by plane table surveys made in connection with the present investigation of the tidal-flood problem at Stamford.

TABLE B-6

TIDAL ELEVATIONS VS. FREQUENCY DATA

HURRICANES AND SEVERE STORMS

Stamford, Connecticut

Hurricane or Storm	Estimated Maximum Tidal Elevation (ft. - MSL)	Percent Chance of Occurrence in any one year(1) 1815-1956	1938-1956
Hurricane, 21 Sept.1938	11.0 (2)	0.4	2.6
Hurricane, 24 Aug. 1893	10.3 (3)	1.1	
Hurricane, 31 Aug. 1954	10.3 (2)	1.8	7.9
Hurricane, 23 Sept.1815	10.2 (4)	2.5	
Storm, 25 Nov. 1950	9.5 (5)		13.2
Hurricane, 14 Sept.1944	9.2 (4)		18.4
Storm, 7 Nov. 1953	9.2 (5)		23.7
Storm, 30 Nov. 1944	8.0 (4)		29.0
Storm, 31 Oct. 1947	7.9 (4)		34.2
Storm, 14-16 Oct. 1955	7.9 (5)		39.5
Storm, 27 Nov. 1940	7.4 (4)		44.7
Storm, 29 Nov. 1945	7.4 (4)		50.0
Storm, 8 Dec. 1950	7.4 (4)		55.3
Storm, 4 May 1954	7.2 (4)		60.5
Storm, 21 April 1940	7.1 (4)		65.8
Storm, 16 Jan. 1945	7.1 (4)		71.0
Storm, 12 Nov. 1947	7.1 (4)		76.3
Storm, 23 Oct. 1953	7.1 (4)		81.6
Storm, 26 Oct. 1943	7.0 (4)		86.8
Storm, 10 May 1945	7.0 (4)		92.1
Storm, 20 April 1940	7.0 (4)		97.4
Storm, 22 May 1951	7.0 (4)		100.0

(1) Calculated plotting position:-

$$P = \frac{100(M-0.5)}{Y} \quad \text{where}$$

P= percent chance of occurrence in one year.
M= number of the event.
Y= number of years of record.

(2) Based on high water marks at Stamford.
(3) Estimated from newspaper account.
(4) Stage related from gage reading at Bridgeport, Connecticut.
(5) Tide gage reading at Stamford.

TABLE B-7

PONDING FROM RUNOFF IN PAST HURRICANES AND THE OCTOBER 1955 STORM

HURRICANE PROTECTION PLAN "E"

Stamford, Connecticut

STORM	Rainfall		Ponding of Runoff					
			West Branch Protection		East Branch Protection		Westcott Cove Protection	
	Total (inches)	12-Hr. (inches)	Vol. ac.ft.	Elev. (1) (ft. msl)	Vol. ac.ft.	Elev. (ft.msl)	Vol. ac.ft.	Elev. (ft.msl)
Hurricane, 1938	11.0(2)	3.9(2)	0	2.5	86	2.0	0	4.0 & 7.0(3)
Hurricane, 1944	11.1(2)	3.9(2)	2	2.7	255	5.0	5.	6.4 & 7.2 (est.)(3)
Hurricane, 1954	2.6	2.3	0	2.5	82	1.9	0	4.0 & 7.0(3)
Storm, Oct. 1955	13.3	7.9	33	5.1	375	6.6	20	7.5 & 7.5(3)

(1) In low area at Pacific and Crosby Streets; storage reflects pumping at existing station and new station included in Plan "E".

(2) Based on records at Mineola, L.I.

(3) At east end of Rippowam Road where damage begins at an elevation of about 7.3 feet msl.

B-10. DESIGN STORM-TIDE DERIVATION

A memorandum dated 17 May, 1957, to the Beach Erosion Board from the Department of Oceanography of the Agricultural and Mechanical College of Texas, in connection with research work being conducted by them under contract, contains the results of computations of hurricane surge potentials in Long Island Sound and forms the basis for the derivation of a design surge at Stamford. The evaluation of design storm surges for Long Island Sound was made by verification of analytical computations with information on observed high water levels in the Sound during the 1938 hurricane. The wind and barometric pressure patterns utilized in the 1938 hurricane problem were taken from U.S. Weather Bureau Memorandum HUR 7-8 dated 1 June 1956. Computations were made for design hurricanes advancing at speeds of 30 to 40 knots. From a surge viewpoint, the latter condition is most critical in the eastern and western portions of the Sound, and the 30-knot hurricane the most critical in the central portion. The design hurricane corresponds to a transposition of the 1944 hurricane which was especially severe off Cape Hatteras, with wind field and pressures as specified in U.S. Weather Bureau Memoranda Nos. HUR 7-11 and 7-13, dated 15 June 1956 and 1 August 1956. This storm was considered to move northward along a path that would cause the region of maximum winds and highest surge to be directed into the eastern entrance of the Sound, off Montauk Point, Long Island. In the Stamford area, to allow for differences between observed and computed surges in the 1938 hurricane, the computed design surge for the 40-knot storm was modified by the ratio of the observed to the computed 1938 surge. To determine a design stillwater level, the design surge was added to a high spring tide equivalent to the spring tide predicted for 24 and 25 September 1957, as shown on Plate B-7. This gave a design stillwater level of 16 feet msl at Stamford, derived as follows:

Surge, design storm (40-knot speed)	10.4 feet
High spring tide	5.6 feet msl
Design stillwater level	16.0 feet msl

The ratio of the design surge to the 1938 surge is approximately 1.3

B-11. WAVE HEIGHTS AND RUNUP

Design wave heights and wave runup have been derived for the proposed barrier, dikes, and walls in the West Branch, East Branch, and Westcott Cove areas of Stamford. They were determined for conditions of a 35 mph wind, from the west southwest coincident with a design peak surge of 10.4 feet and a spring tide of 5.5 feet msl.

Significant wave heights have been calculated for one-mile fetches along the center of the Sound, for a distance of 14 nautical miles, starting from Huckelberry Island, off Davenport Neck, New Rochelle, at the western end of the Sound. A 6-foot wave with a period of 5.7 seconds was computed for the entrances of Stamford Harbor and Westcott Cove. Inside the harbor, this wave was reduced to a height of 3.6 feet and a 4-second period due to refraction. A refraction coefficient of 0.60 was used which was derived from method contained in Beach Erosion Board Bulletin, Special Issue No. 1, using a water depth of 28 feet, a wave length of 166 feet, and an angle of 50 to 60 degrees between a west southwest fetch and the Stamford shore. The existing breakwaters, with top elevation of 8.6 feet msl, would be submerged about 7 feet and are not considered to be effective in reducing wave heights under design hurricane conditions. The height and period of the significant wave at the mouth of the East Branch have been determined to be 3.6 feet and 4 seconds, respectively. Due to refraction and to the diffraction effect of the narrow West Branch, this wave has been reduced to one with a height and period of 2 feet and 2 seconds in this Branch.

The significant wave at the head of Westcott Cove is also one of 2-foot height and 2-second period. This is due to the leeward location of the cove in a west southwesterly wind and to the fact that waves moving easterly along the axis of the Sound have to make a sharp turn of nearly 90° before reaching the head of the cove.

Wave heights also have been computed for a 95 mph wind from the south such as would be experienced in the event of a hurricane centered over New York City. See paragraph B-10. Under such conditions, the tidal surge at Stamford would not be appreciable. The tidal surges that enter Long Island Sound and cause flooding along the Connecticut Coast originate from hurricanes moving along tracks passing near Montauk Point, L.I., east of Stamford. Calculations of wave heights at Stamford for a 95 mph wind have been based on a fetch from the north shore of Long Island and a stillwater elevation of 7.8 feet msl. This elevation equals a high spring tide at 5.6 feet msl plus a wind setup for 2.2 feet. A significant wave with a height of 10 feet and a period of 6.5 seconds would reach the breakwaters at the mouth of the harbor. The waves hitting the breakwaters would be broken. Those that passed through the 800-foot gap between the breakwaters would be affected by the many small islands in the harbor area and further reduced by diffraction and refraction. It is estimated that the waves reaching the protective works in the East Branch would have a height of approximately 4 feet and a period of 4 seconds; and those reaching the protective structures along the West Branch would have a height of 2 feet and a period of 2 seconds. The significant waves entering Westcott Cove, under the same wind condition, would be broken

on the shore before reaching the protective structures. A significant wave is the average of the highest one-third of the waves in a wave train. It will be exceeded by about 13 percent of all the waves in the train. Data on wave heights and runup are summarized in Table B-8 on the following page. The runup figures in the table indicate the vertical rise of water above a still level of 16 feet msl in a design hurricane. The computation of runup values is based on walls of concrete construction and dikes with rubble slopes of rough angular stones. Maximum wave heights will be approximately 1.6 times greater than the significant wave heights noted in Table B-8 and corresponding wave runup also will be greater than indicated. Runup data were derived from curves, representing the results of laboratory studies, contained in Beach Erosion Board Technical Report No. 4.

TABLE B-8

DESIGN WAVE HEIGHTS AND RUNUP

HURRICANE PROTECTION PLAN "E"

Stamford, Connecticut

Structure and Locations	Top Elev. (ft. msl)	Seaward Slope	Significant Wave Height (ft.)	Wave Runup (1) (ft.)
		West Branch Protection		
Wall - North of Power Co.	17	Vertical	2.0	4.0
Wall - On Power Co. property	17	Vertical	2.0	2.5
Dike	18	1 on 1.5	2.0	1.2
		East Branch Protection		
Dike - Closure at west end	18	1 on 1.5	3.6	3.1
Barrier - West of gate	18	1 on 2.5	3.6	3.0
Gate	18	Vertical	3.6	5.8
Barrier - East of gate	18	1 on 2.5	3.6	3.0
Dike - Closure at east end	18	1 on 1.5	3.6	3.1
		Westcott Cove Protection		
Dike	18	1 on 1.5	2.0	1.2

(1) Above stillwater level of 16.0 feet msl.

B-12. OVERTOPPING

The amount of overtopping is important not only in the design of a safe structure but also from the standpoint of flooding that may be caused by the ponding of the overtopping water. Rates of overtopping were determined for a peak stillwater level of 16 feet msl and for several lower elevations in the design hurricane. The heights of a significant wave in the design hurricane, shown in Table B-8, were used in all computations. The duration of overtopping is estimated from the tide graph for the design hurricane shown on Plate B-9. Overtopping data were obtained by interpolation and extrapolation of the curves in Beach Erosion Board Technical Manual No. 64 which relate the rate of overtopping in cubic feet per second per foot of length to the crest elevation above stillwater, with wave heights as a third variable. These curves were derived from data gathered in experimental wave tank tests made at the Waterways Experiment Station for the Beach Erosion Board and therefore are for uniform waves, mechanically generated. To simulate the actual wave train in nature, consideration was given to the overtopping associated with each wave height in the wave spectrum. These were weighted according to the relative frequency of occurrence of the particular height (as given by statistical analysis of wave height frequency) and then summated in order to get the final value of overtopping associated with a wave train of given significant height.

A key to the relative importance of the overtopping of proposed protective structures in a design hurricane may be found in Table B-8. An examination of this table indicates that the top of wave runup in a design hurricane will range from 0.0 to 3.0 feet over the top of structures along the West Branch and 1.0 to 3.8 over the protective works in the East Branch. There will be no overtopping of the dike in the Westcott Cove Area. No overtopping is indicated in the event of a recurring 1938 hurricane with a peak stillwater level 5 feet below that of a design hurricane, except at the barrier across the East Branch where minor overtopping would be sustained owing to the deep water in this area. Overtopping of the East Branch barrier can begin when the water level in Stamford Harbor is at an elevation of 9.0 feet msl. Overtopping of protective works in the East Branch, however, is of relatively minor consequence owing to the large storage capacity in the Branch above the barrier. Estimates of the overtopping to be anticipated in connection with Plan "E" protective works at Stamford, in the event of a design hurricane, are summarized in Table B-9 on the following page.

TABLE B-9

OVERTOPPING OF PROTECTIVE WORKS - DESIGN HURRICANE

HURRICANE PROTECTION PLAN "E"

Stamford, Connecticut

Protection	Water Surface At Which Overtopping Begins & Ends (feet msl)	Duration (hrs.)	Average Rate (cfs)	Volume (ac.ft.)	Maximum Pool Elevation (feet msl)
West Branch	11.8	2	250	40[1]	5.3
East Branch	9.0	3	760	189	3.9
Westcott Cove	-	0	0	0	-

(1) With no pumping.

B-13. CURRENT VELOCITIES IN NAVIGATION CHANNEL

The width of the gated navigation opening determines the current velocities through the opening. Computations of velocities in the navigation opening were based on routing calculations predicated on the storage capacity in the East Branch, above the barrier, and the formula $Q=CA\sqrt{2gh}$, where "H" equals the difference between the water surface elevations on the lower and upper sides of the barrier, and "C" is a coefficient of discharge assumed to equal 0.75. This formula does not evaluate all the variable losses from contraction, expansion, friction, wind, and other indeterminate factors, but it is believed that the adopted coefficient provides reasonable results.

It has been determined by the routing calculations that the average velocity in the cross-section of the opening is about 0.8 knot at both the flood and ebb of a high spring tide. It is estimated that the maximum current in the cross-section would be at the center of the opening, near the surface, and would equal approximately 1.0 knot, or about 30 percent greater than the 0.8 knot average. The 75-foot width of opening is sufficiently large, compared to the pool area above the barrier, to cause an insignificant effect on the tidal regimen upstream of the barrier.

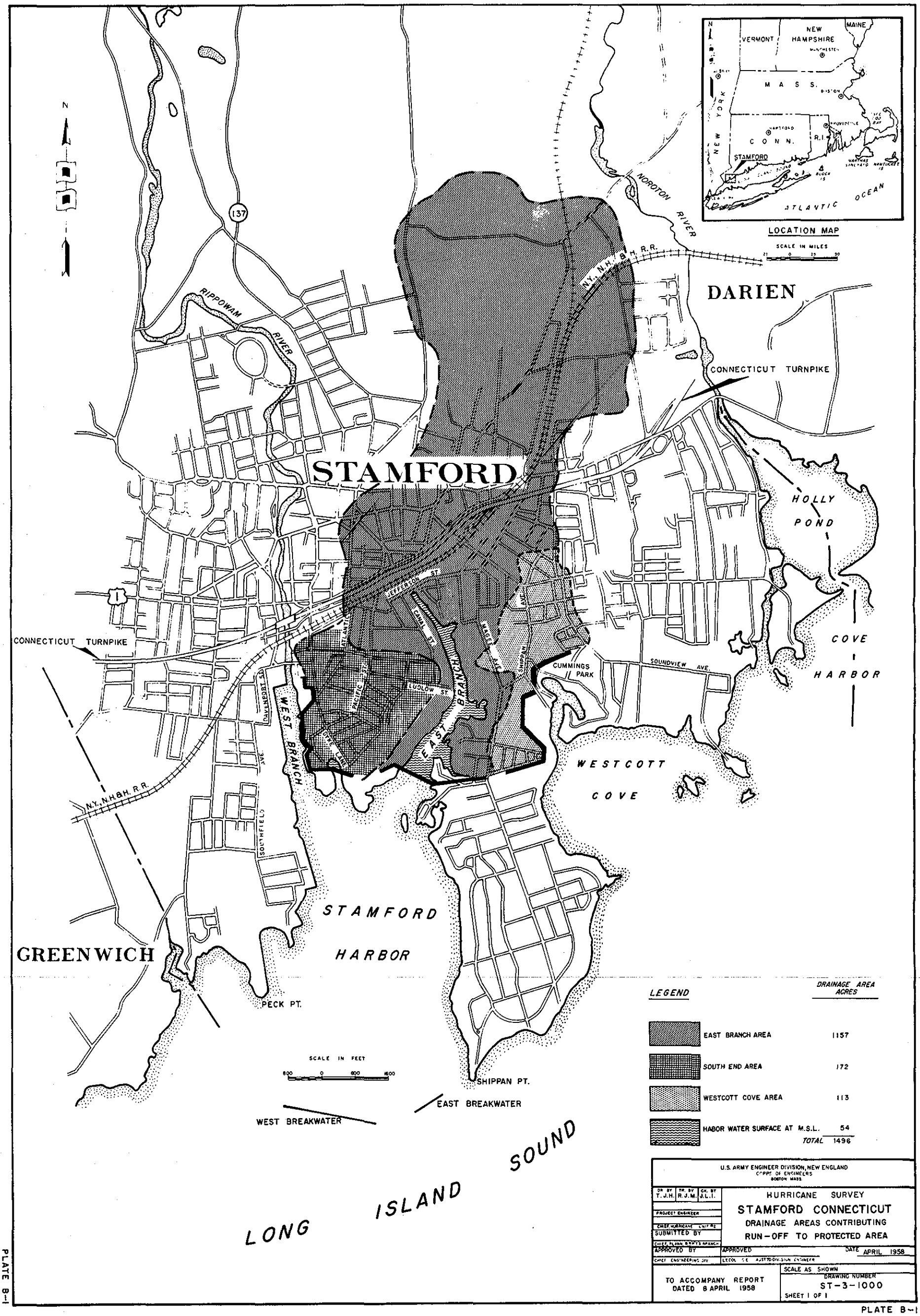


PLATE B-1

PLATE B-1

ACCUMULATED PRECIPITATION IN INCHES

0
2
4
6
8
10
12
14
16

13.29" STAMFORD (Non-Recorder)

10.81" Brentwood, L.I. (Recorder)

10.56" Candlewood Lake, Conn. (Recorder)

7A 14 7P | 7A 15 7P | 7A 16 7P | 7A 17 7P

OCTOBER 1955

HURRICANE SURVEY

STAMFORD CONNECTICUT

MASS CURVES OF RAINFALL

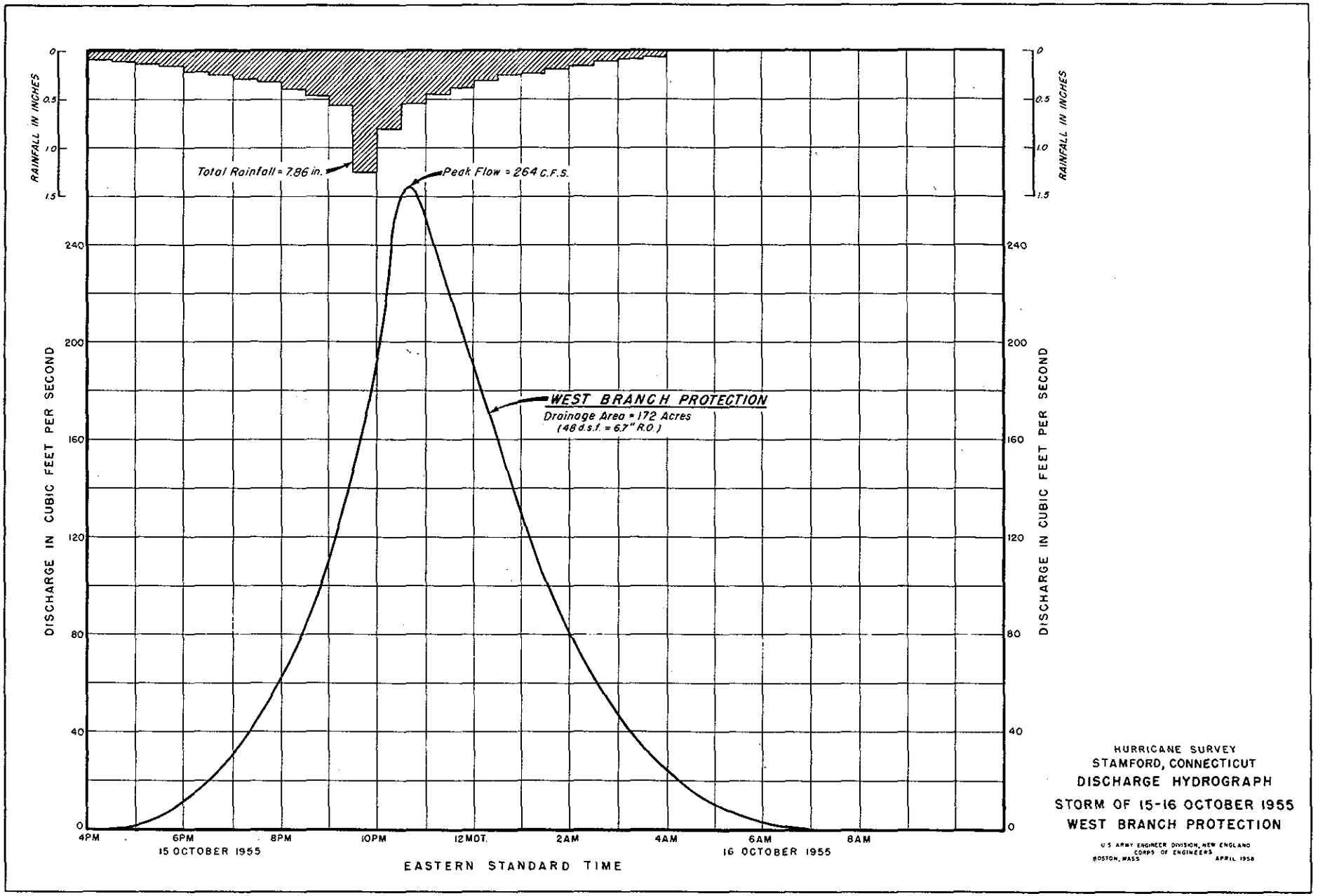
STORM OF 14-17 OCTOBER 1955

U.S. ARMY ENGINEER DIVISION, NEW ENGLAND

CORPS OF ENGINEERS

BOSTON, MASS. APRIL 1958

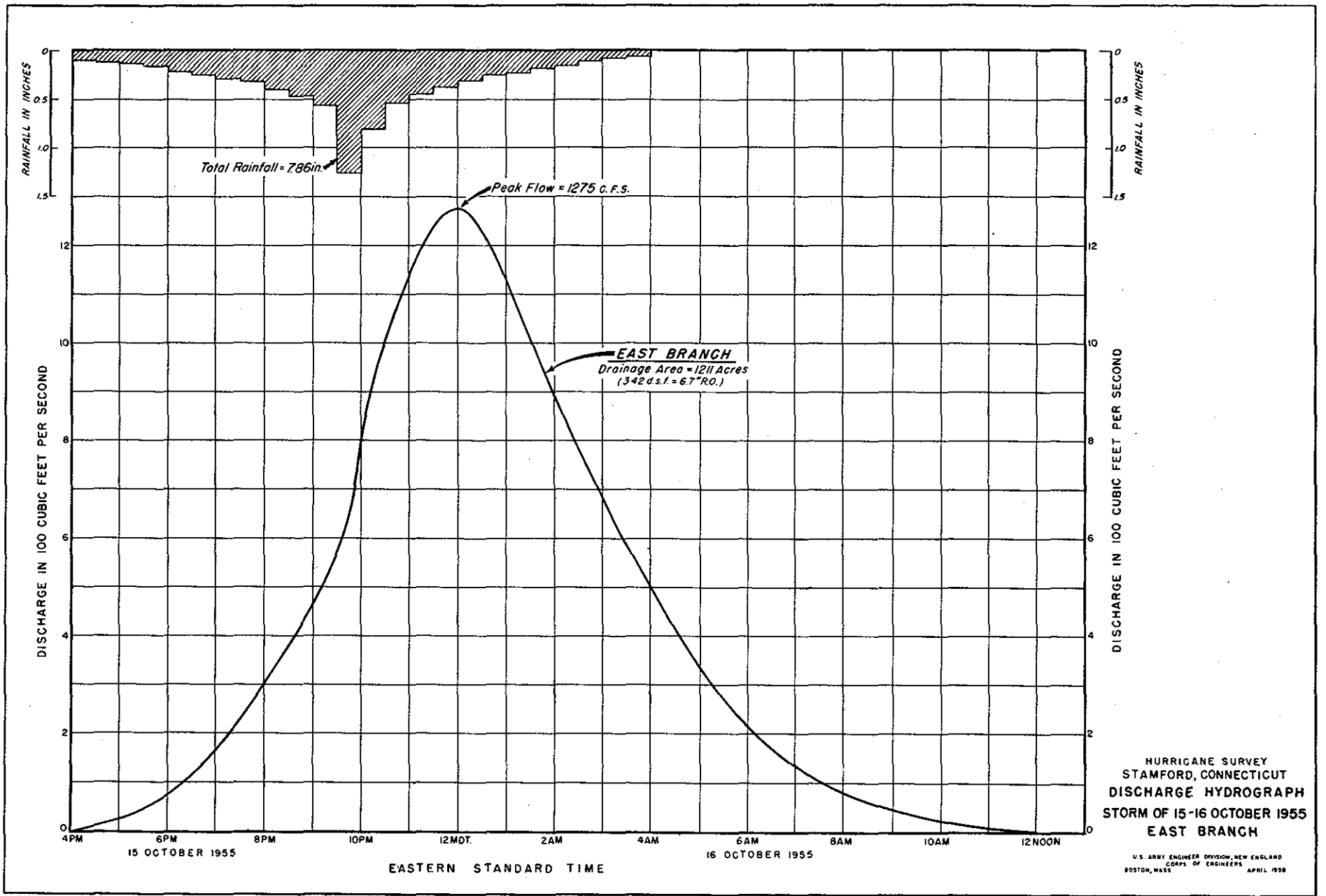
PLATE B-2



HURRICANE SURVEY
STAMFORD, CONNECTICUT
DISCHARGE HYDROGRAPH
STORM OF 15-16 OCTOBER 1955
WEST BRANCH PROTECTION

U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
BOSTON, MASS. APRIL 1958

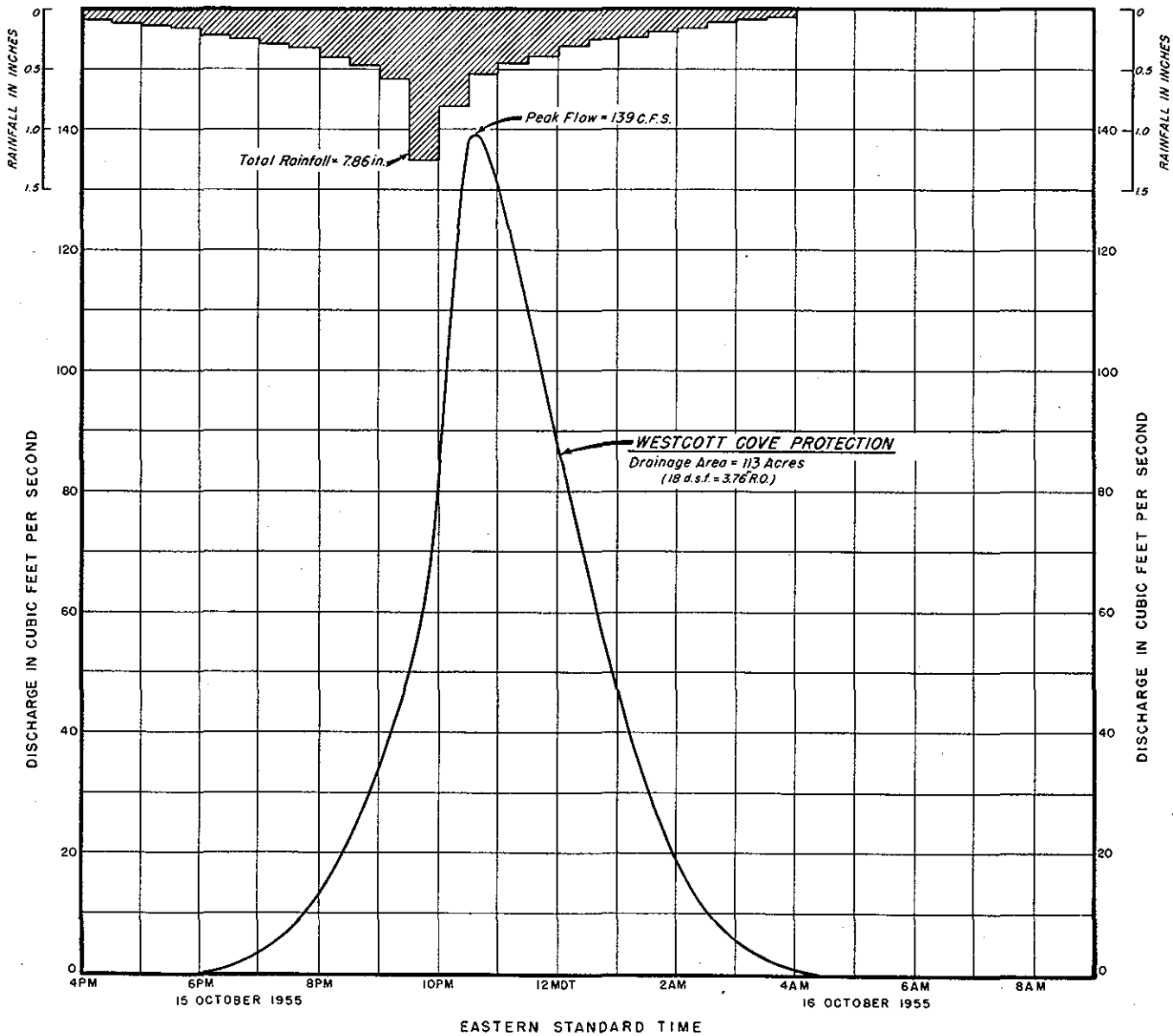
PLATE B-3



HURRICANE SURVEY
STAMFORD, CONNECTICUT
DISCHARGE HYDROGRAPH
STORM OF 15-16 OCTOBER 1955
EAST BRANCH

U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
BOSTON, MASS.
APRIL 1958

PLATE B-4



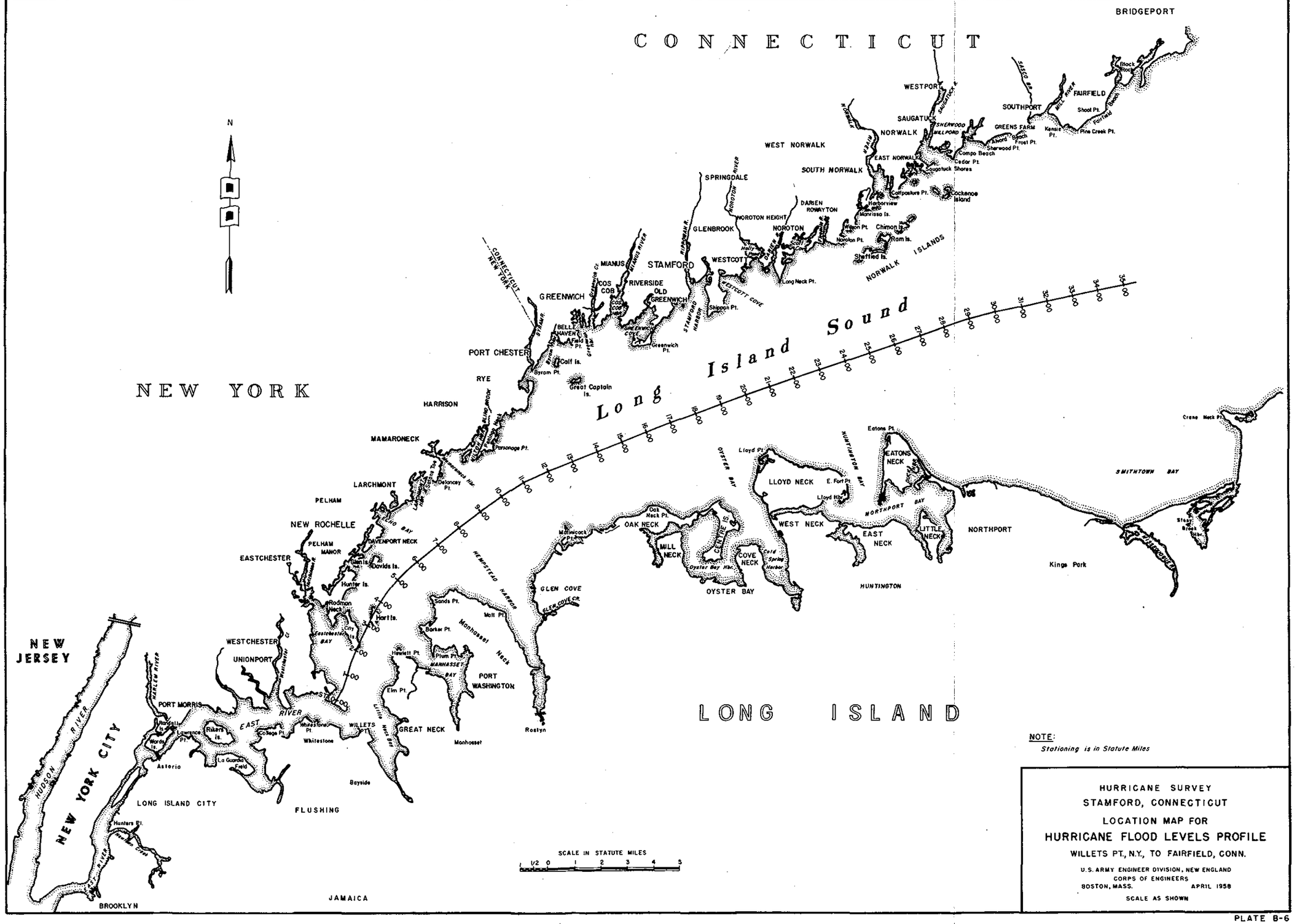
HURRICANE SURVEY
STAMFORD, CONNECTICUT
DISCHARGE HYDROGRAPH
STORM OF 15-16 OCTOBER 1955
WESTCOTT COVE PROTECTION

U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
BOSTON, MASS.
APRIL 1958

PLATE 8-5

CORPS OF ENGINEERS

U. S. ARMY



NOTE:
Stationing is in Statute Miles

HURRICANE SURVEY
STAMFORD, CONNECTICUT
LOCATION MAP FOR
HURRICANE FLOOD LEVELS PROFILE
WILLETS PT., N.Y., TO FAIRFIELD, CONN.

U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
BOSTON, MASS. APRIL 1958
SCALE AS SHOWN

PLATE B-6

CORPS OF ENGINEERS

U. S. ARMY

NEW YORK — CONNECTICUT

GREENWICH — STAMFORD — DARIEN — NORWALK — WESTPORT — FAIRFIELD

STAMFORD HARBOR

WILLETS POINT · EASTCHESTER BAY · CITY ISLAND · DAVENPORT NECK · LARCHMONT HARBOR · SATANS TOE · DELANCEY POINT · MAMARONECK HARBOR · PENNINGO NECK · PARSONAGE POINT · PORT CHESTER HBR. · BYRAM POINT · BYRAM RIVER · BYRAM HARBOR · GREAT CAPTAIN IS. · DELL LEDGE · FIELD POINT · GREENWICH HARBOR · GREENWICH CREEK · COS COB HARBOR · MANUS · COS COB · GREENWICH POINT · GREENWICH COVE · OLD GREENWICH · RIPPOWAM RIVER · SHIPPAN POINT · WESTCOTT · HOLLY POND · DARIEN RIVER · LONG NECK POINT · SCOTT COVE · FIVE MILE RIVER · ROWAYTON · NORTON POINT · WILSON POINT · HARBORVIEW · NORWALK RIVER · CALFPASTURE POINT · SAUGATUCK SHORES · SAUGATUCK RIVER · CEDAR POINT · COMPO BEACH · SHERWOOD POND · SHERWOOD POINT · ALVORD BEACH · FROST POINT · SASCO BROOK · MILL RIVER · KENSIE POINT · PINE CREEK POINT · FAIRFIELD BEACH

DESIGN HURRICANE TIDAL FLOOD

HURRICANE OF SEPTEMBER 21, 1938 TIDAL FLOOD

HURRICANE "CAROL" AUGUST 31, 1954 TIDAL FLOOD

HIGH SPRING TIDE

MEAN HIGH WATER

MEAN SEA LEVEL

MEAN LOW WATER

BYRAM RIVER (H.W. MARKS NO. 600-604, INCL.)

GREENWICH HARBOR (H.W. MARKS NO. 614)

COS COB HARBOR

STAMFORD OUTER HARBOR GREENWICH COVE (STAMFORD, CONN. H.W. MARKS NO. 627-639, INCL.)

STAMFORD HARBOR (STAMFORD, CONN. H.W. MARKS NO. 650-664, INCL.)

SAUGATUCK RIVER (H.W. MARKS NO. 712 & 721-736, INCL.)

ELEVATION IN FEET ABOVE MEAN SEA LEVEL

STATUTE MILES — LONG ISLAND SOUND

LEGEND:

- ⊡ SEPTEMBER 21, 1938 HIGH WATER.
- ⊙ AUGUST 31, 1954 HIGH WATER.
- 675 NUMBER IDENTIFIES HIGH WATER MARK.

HURRICANE SURVEY

STAMFORD, CONNECTICUT

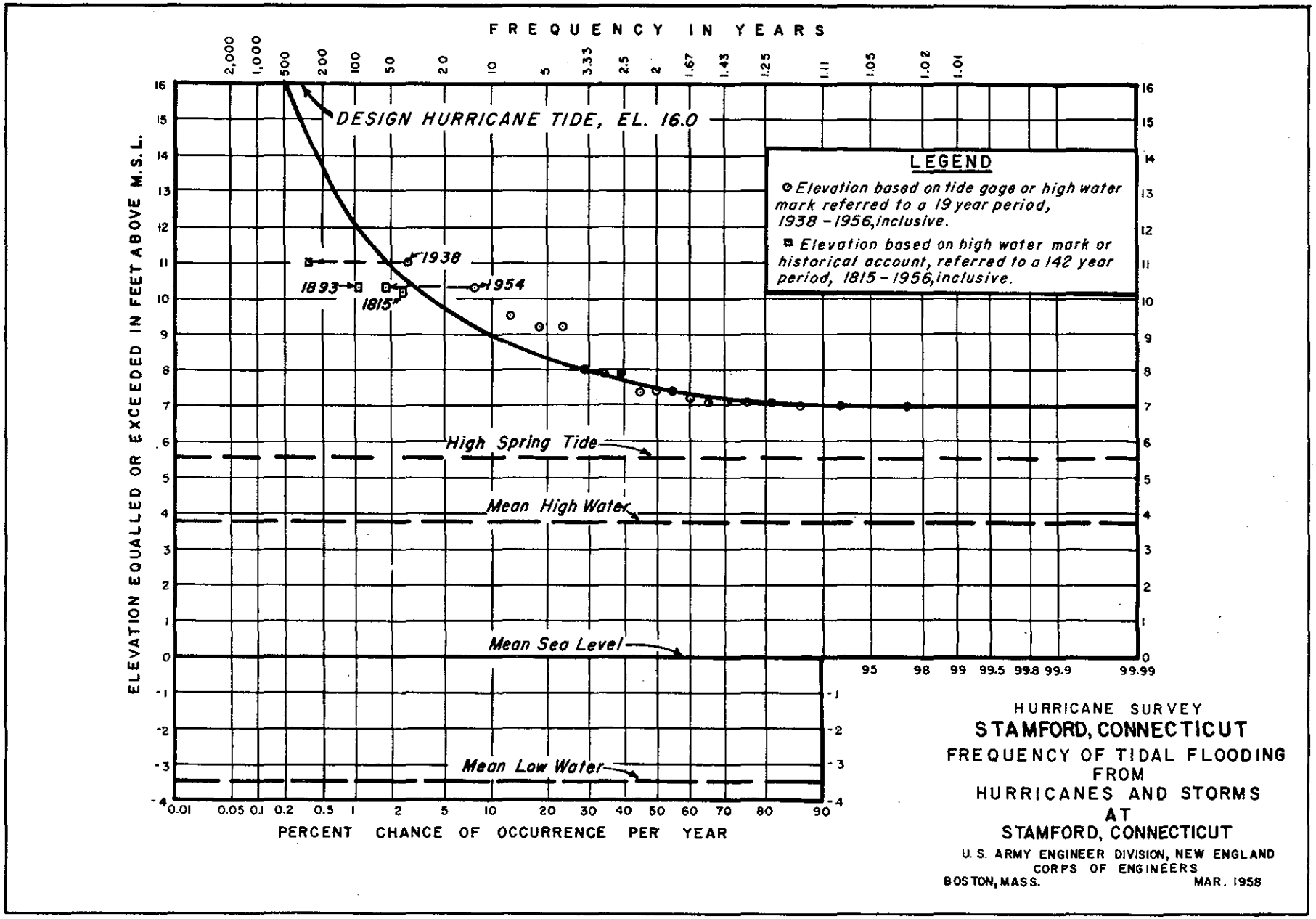
HURRICANE FLOOD LEVELS PROFILE

WILLETS PT, N.Y. TO FAIRFIELD, CONN.

U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
BOSTON, MASS. APRIL 1958

SCALE AS SHOWN

PLATE 8-7



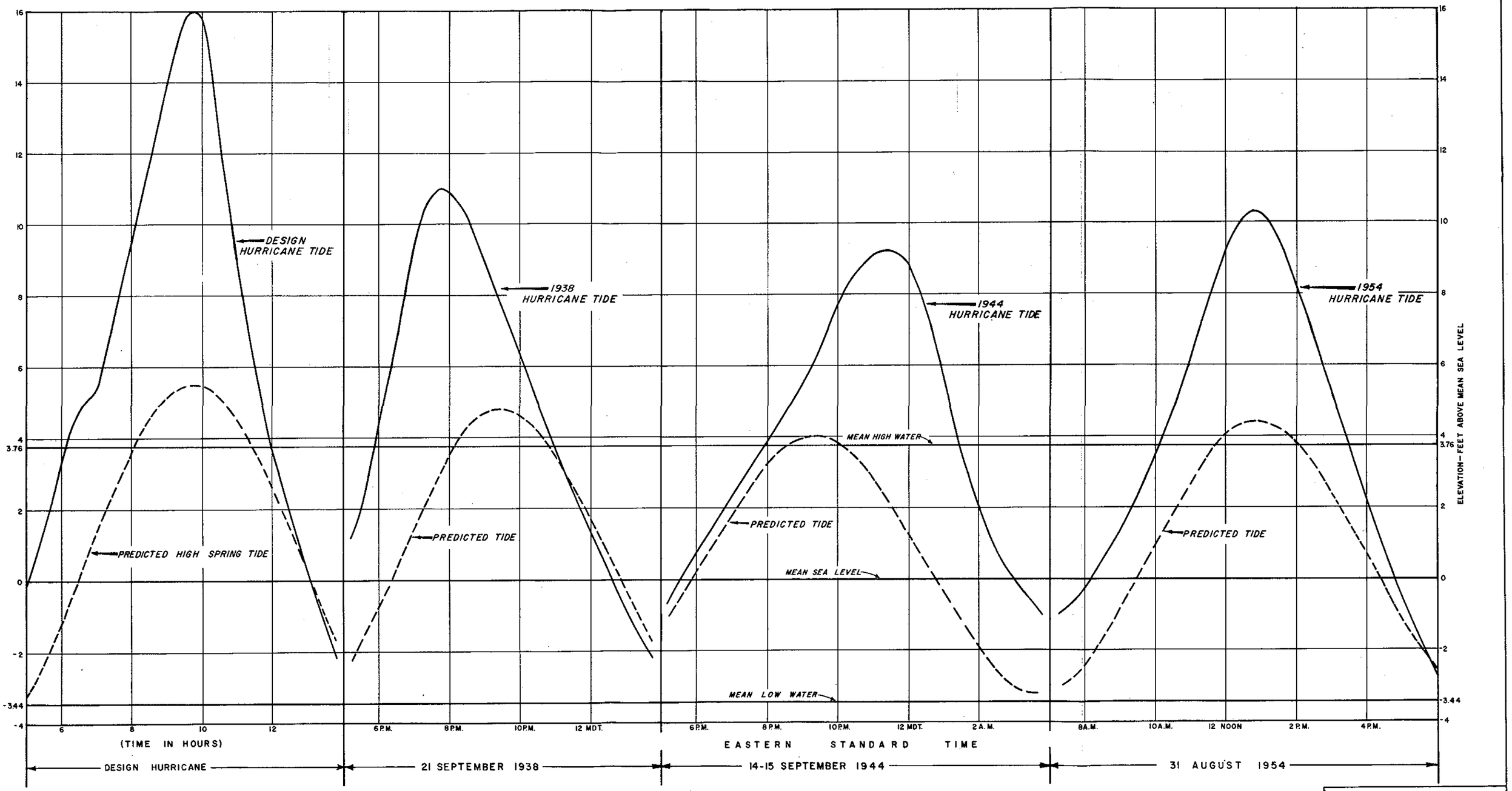
HURRICANE SURVEY

STAMFORD, CONNECTICUT

FREQUENCY OF TIDAL FLOODING
FROM
HURRICANES AND STORMS
AT
STAMFORD, CONNECTICUT

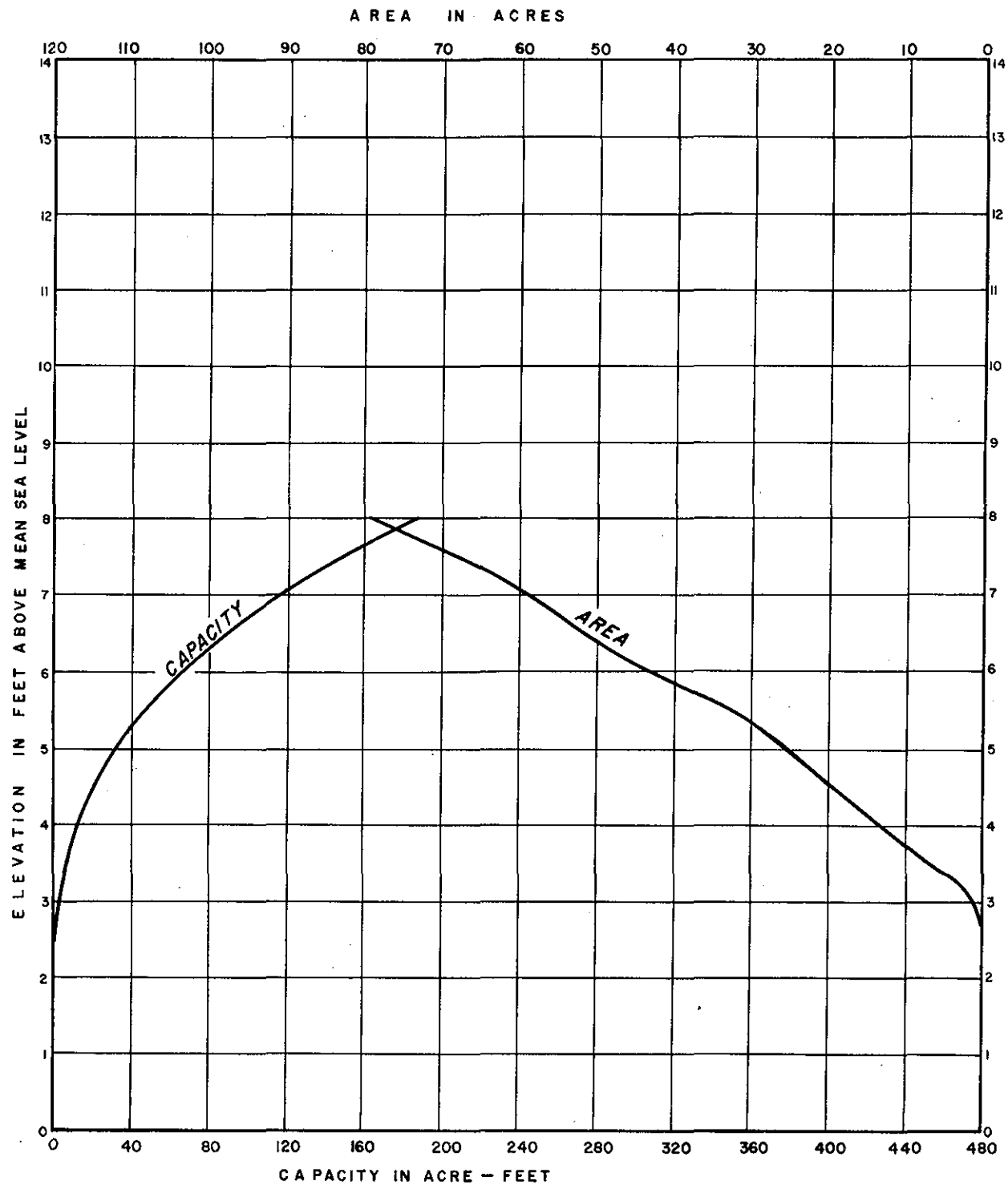
U. S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
BOSTON, MASS. MAR. 1958

PLATE B-8



HURRICANE SURVEY
STAMFORD, CONNECTICUT
TIDE CURVES
DESIGN, 1938, 1944, & 1954 HURRICANES
U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
BOSTON, MASS. MAR 1958

PLATE B-9



HURRICANE SURVEY

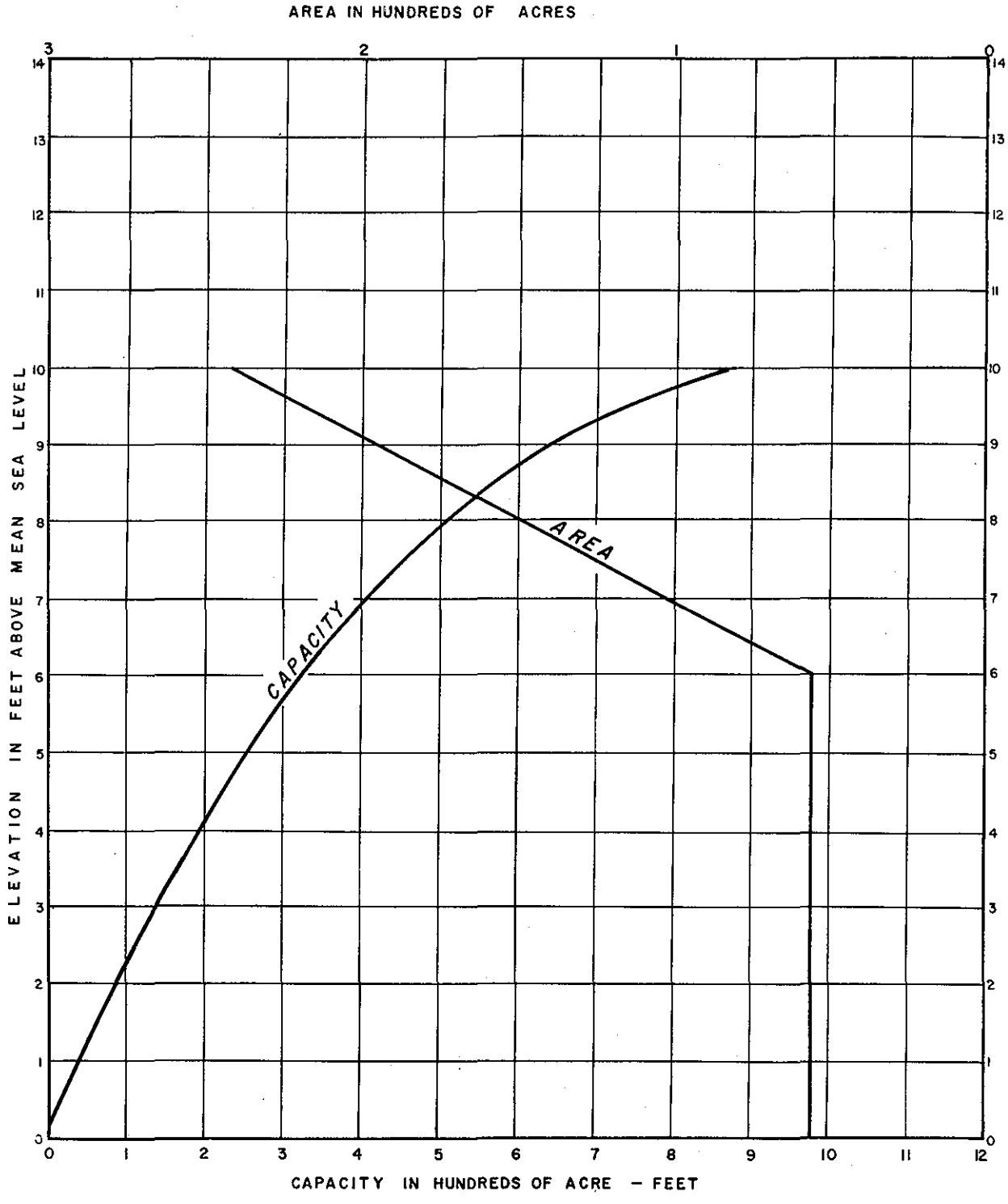
STAMFORD CONNECTICUT

AREA AND CAPACITY CURVES

WEST BRANCH PROTECTION

U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
BOSTON, MASS MAR. 1958

PLATE B-10



HURRICANE SURVEY

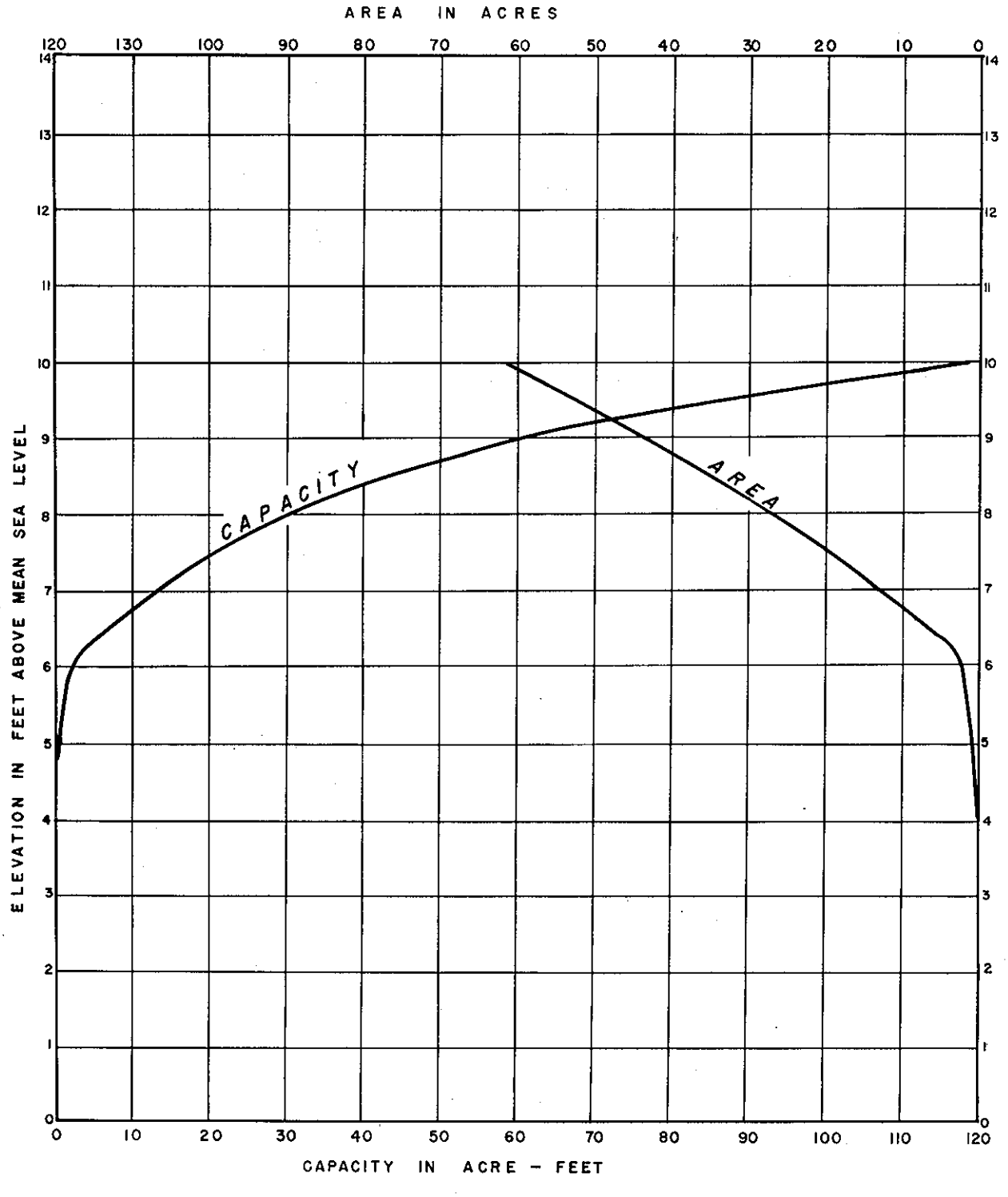
STAMFORD CONNECTICUT

AREA AND CAPACITY CURVES

EAST BRANCH

U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
BOSTON, MASS. MAR. 1958

PLATE B-11



HURRICANE SURVEY

STAMFORD CONNECTICUT

AREA AND CAPACITY CURVES

WESTCOTT COVE PROTECTION

U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
BOSTON, MASS. MAR. 1958

PLATE B-12

APPENDIX C

HISTORY OF HURRICANE AND OTHER STORM OCCURRENCES

APPENDIX C

HISTORY OF HURRICANE AND OTHER STORM OCCURRENCES

C-1. GENERAL

In order to determine the possibility of future hurricane occurrences, a review has been made of historical data on past hurricanes that have struck or threatened the coast of Connecticut. Since the eastern entrance of Long Island Sound lies in the path of hurricanes moving into New England from the south, the Connecticut shoreline, on the north of the Sound, has frequently been subject to tidal flooding from hurricane surges moving west up the Sound. The records indicate that the coast of Connecticut, including Stamford, has experienced or has been threatened by hurricane tidal flooding upon 58 occasions since 1770. The greater number of these hurricanes, owing to the locations of their paths, did not cause tidal flooding along the Connecticut shore. However, they did present a potential threat of such flooding. Of the 14 hurricanes that have caused tidal flooding, the 5 greatest, as far as can be determined from existing records, are listed below in their estimated order of magnitude:

21 September 1938
24 August 1893
31 August 1954
15 September 1815
14 September 1944

In recent years, the hurricanes that have caused tidal flooding along the coasts of Rhode Island and southern Massachusetts caused flooding along the Connecticut coast. Prior to 19 October 1770, four hurricanes are known to have affected the coastal areas of Massachusetts and Rhode Island. The two earliest of these storms, namely those of 15 August 1635 and 3 August 1638, caused extensive tidal flooding, probably the greatest ever experienced in New England during the past 200 to 300 years. Since there was very little development along the Connecticut shore until after 1638, there are no available records to indicate that these storms affected Long Island Sound. It is reasonable to assume, however, that they did cause inundation of the coastal lowlands of Connecticut.

Since the extent of flood damages is relative to the degree of development in the areas flooded, the early great hurricanes were not nearly as damaging as those of the present century. As a matter of fact, the two earliest hurricanes of record in New England, which, according to history, must have been very severe,

occurred prior to the settlement of Stamford and other cities and towns along the Connecticut coast. The recurrence of these two hurricanes under present conditions would cause extensive damages, possibly in excess of the damages sustained in September 1938.

An examination of the U.S. Coast and Geodetic Survey tide-gage records for New London, Connecticut, and Willets Point, New York, and of local staff-gage records at Bridgeport, Connecticut, indicates that there have been 21 occasions, other than hurricane experiences, during the years 1938 through 1956, inclusive, when storms or other meteorologic conditions caused the tide at Stamford to reach an elevation of 6.6 feet msl or higher. This elevation is approximately one foot above the level that would be reached in a high gravitational spring tide. The five highest tides so experienced at Stamford during this 19-year period are tabulated below:

Date	Tide (feet msl)
25 Nov. 1950	9.5
7 Nov. 1953	9.2
30 Nov. 1944	8.0
14-16 Oct. 1955	7.9
31 Oct. 1947	7.9

C-2. SUMMARY OF HURRICANE AND STORM OCCURRENCES

A summary has been prepared, see Table C-1, which lists all hurricanes known to have directly affected the coast of Connecticut, and, also, all hurricanes known to have threatened the area. In the latter case, a slight change in meteorological conditions could have caused any of these hurricanes to follow a course more critical to Long Island Sound, thereby subjecting the Connecticut coastal area to tidal flooding. The following classifications indicate the effect of the recorded hurricane occurrences on the Connecticut coast:

Type "A": Hurricanes causing tidal flooding.
Type "B": Hurricanes causing damage from wind and rainfall; no evidence of tidal flooding.
Type "C": Hurricanes threatening the area; no damage.

Of the 58 hurricanes of record, listed in Table C-1, that have either caused or threatened damage along the Connecticut coast since 1770, 14 are of type "A," 17 of type "B," and the

remaining 27 of Type "C." Thirty-nine of the listed hurricane experiences (7 type "A," 10 type "B," and 22 type "C,")have occurred during the period from 1901 to 1956. The fact that there is a record of 39 hurricanes in this 56-year period, as compared with 19 in the 131-year period from 1770 to 1900, is not considered indicative of a greater trend in hurricane activity in recent years but to a lack of records and information on storms prior to 1900.

TABLE C-1

HISTORICAL HURRICANES

Connecticut Coast

Date of Hurricane	Category (1)	Source of Data	Remarks
1635, Aug. 15	-	(2)(3)	Great tidal surge along coast of R.I. Effect on Connecticut coast not known.
1638, Aug. 3	-	(3)	Historical account indicates greatest tidal flooding ever experienced along Mass. and R.I. coast. Effect on Conn. coast not known.
1723, Oct. 31	-	(3)	Very high tides in R.I.; considerable damage. Effect on Conn. coast not known.
1757 -	-	(2)	Atlantic Coast hurricane, Florida to Boston, Mass. Effect on Conn. coast not known.
1761, Oct. 24	-	(3)	Very high tides in Narragansett Bay, R.I. Damage from wind and water.
1770, Oct. 19-20	B	(3)	A violent storm; immense loss of life and property along the coast. Report of boat damage at New London, Conn.
1773, Aug. 19	C	(2)(3)	Passed near Boston, Mass. "Abundant showers" in Conn.
1787, Sept. 19	B	(3)	Reports of damage at Stamford and Norwalk, Conn.
1788, Aug. 19	C	(2)	Affected western New England; much damage in Conn. and Mass.

(Footnotes are at end of table.)

TABLE C-1 (Cont'd)

Date of Hurricane	Category (1)	Source of Data	Remarks
1804, Sept. 3-9	C	(2)	Severe storm; passed over Cape Cod, travelling northeast. No account of damage in Conn.
1804, Oct. 9-10	B	(2)(3)	Reports of minor wind and rain damage.
1815, Sept. 18-24	A	(2)(3)	Very high tide; considerable damage along Conn. coast from tidal flooding.
1821, Sept. 1-4	A	(2)(3)	Wind damage to boats and homes. Tidal flood damage at New London, Conn.
1829, July 24	C	(2)(3)	Reported to have been felt in Boston, Mass. No accounts of damage in Conn.
1841, Oct. 3-6	B	(2)(3)	Violent winds and heavy rain; reports of wind damage at Hartford, Connecticut
1854, Sept. 6-14	C	(2)(3)	Severe in southern states; passed over New England, near Boston. Heavy rain and high winds at New Haven, Connecticut.
1866, Oct. 29,30	B	(2)(3)	Reports of wind damage.
1869, Sept. 8	A	(2)(3)	Tidal-flooding at Mystic, Connecticut.
1877, Sept. 21-Oct. 5	C	(2)(3)	Path was south of Long Island and Nantucket. No accounts of damage in Conn.
1878, Oct. 18-24	A	(2)(3)	Reports of wind damage at Bridgeport; very high tide at Greenwich, Conn.

TABLE C-1 (Cont'd)

Date of Hurricane	Category (1)	Source of Data	Remarks
1879, Aug. 16-20	B	(2)	Passed over Cape Cod. Damage to crops from wind and rain at Stamford, Conn.
1889, Sept. 1-13	A	(2)(3)	Streets in Stamford flooded by heavy rain. Very high tide at Greenwich, Conn.
1893, Aug. 13-26	A	(2)(3)	Wind, rain, and high tide caused damage along Conn. coast.
1893, Aug. 29	A	(3)	Reports of damage from wind and tide along Conn. coast.
1896, Sept. 3-11	B	(2)(3)	Strong winds and heavy rains; wind damage at Greenwich, Connecticut.
1901, Sept. 9-19	B	(2)(4)	Passed south and east of Cape Cod. Damage from heavy rain at Bridgeport, Connecticut.
1902, June 11-20	C	(2)(3)(4)	Path crossed Buzzards Bay and Cape Cod, moving northeast. Strong winds over L.I. Sound.
1902, June 19-July 1	C	(2)	Center passed over Conn. and southern R.I., traveling southeast; no account of damage.
1902, Oct. 7-13	C	(2)(3)(4)	Path south of Long Island and Nantucket, moving east. Heavy rain and high wind at New Haven, Connecticut
1903, Sept. 13-17	A	(2)(3)	Storm crossed northeastern Pa., moving northwest. High winds and high water along Connecticut coast.

TABLE C-1 (Cont'd)

Date of Hurricane	Category (1)	Source of Data	Remarks
1904, Mar. 9-14	C	(2)(4)	Passed south of Nantucket, moving northeast. No accounts of damage along Connecticut coast.
1904, Sept.8-16	B	(2)(3)	Center passed over northeastern Conn., moving northeast. Reports of wind damage.
1904, Nov. 9-14	B	(2)(4)	Passed south of Nantucket, moving northeast. Reports of wind damage.
1911, Aug.29-30	C	(2)	Passed south of Cape Cod. No accounts of damage in Connecticut.
1912, Sept.11-23	C	(2)	Followed easterly path across southern New England.
1916, July 12-22	B	(2)(4)	Passed over Providence, R.I., heading northeast. Reports of wind and rain damage in Connecticut.
1920, Sept.27-Oct. 1	A	(2)(3)(4)	Storm passed just west of New York, heading north. Reports of damage from high tides along Conn. coast.
1923, Oct.14-19	C	(2)(4)	Passed near Boston, moving northwest. Storm of slight energy.
1924, Aug.16-27	B	(2)(3)	Crossed east tip of Cape Cod, moving northeast. Some damage from strong winds.

TABLE C-1 (Cont'd)

Date of Hurricane	Category (1)	Source of Data	Remarks
1929, Sept.22 - Oct. 4	A	(2)(4)	Moved northeast, passing over eastern New York and northwestern Vermont. High tides caused damage along Connecticut coast.
1933, Aug.24	B	(2)(3)	Driving rain and high tides along Conn. coast.
1933, Sept.10-16	C	(2)(3)	Passed south of Cape Cod, moving northeast. No reports of damage in Conn.
1934, Jun.4-21	C	(2)	Travelled overland from Louisiana; crossed Long Island and Cape Cod, moving northeast.
1934, Sept.5-9	B	(2)(4)	Crossed Long Island and central Conn., moving north. Wind damage along Conn. coast.
1936, Sept.8-26	B	(2)(3) (4)	Passed south of Nantucket, heading northeast. Wind damage along Conn.coast.
1938,Sept.16-22	A	(2)(3) (4)	Most damaging storm to strike southern New England. Tidal-flooding along entire Conn.coast. 8 foot surge at Stamford.
1940, Aug.30 - Sept.3	C	(2)	Passed south of Nantucket, heading northeast. No accounts of damage in Conn.
1940, Sept.11-18	C	(2)(4)	Followed northeasterly path east of Cape Cod. No accounts of damage.
1943, Oct.11-17	C	(2)(4)	Passed east of Cape Cod, moving due north. No accounts of damage.

TABLE C-1 (Cont'd)

Date of Hurricane	Category (1)	Source of Data	Remarks
1944, Jul.31-Aug. 4	C	(2)(4)	Moved northeasterly along path south of Long Island and Nantucket. No accounts of damage.
1944, Sept.9-15	A	(2)(3)	Center passed over Providence, R.I. and south of Boston, Mass. Tidal-flooding along entire Conn. coast; 7.2-foot surge at Stamford.
1944, Oct.13-21	C	(2)(4)	Path crossed over Nantucket and easterly tip of Cape Cod. No accounts of damage.
1945, June 20-27	C	(2)(4)	Followed northeasterly path from Florida to Nova Scotia, passing south of Nantucket.
1945, Sept.12-19	C	(2)(4)	Overland from Florida; passed just west of New York, moving northeast.
1949, Aug.24-29	C	(2)(3)(4)	Travelled overland from northern Florida, crossed center of Maine. High winds at Greenwich, Conn.
1950, Aug. 11-21	C	(2)(4)	Passed south of Nantucket, heading generally northeast. Heavy rain at Greenwich, Conn.
1950, Aug. 31 - Sept.14	C	(2)(3)	Passed south and east of Nantucket, then headed east. No reports of damage in Conn.
1952, Aug. 25 - Sept. 1 ("Able")	C	(2)	Followed northeasterly track, approximately over New York. Heavy rain and high wind at Greenwich, Conn.
1953, Aug. 11-15 ("Barbara")	C	(2)(4)	Followed path south of Long Island and Nantucket.
1953, Aug. 29 - Sept. 8 ("Carol")	C	(2)	Passed east of Cape Cod heading generally north.

TABLE C-1 (Cont'd)

Date of Hurricane	Category (1)	Source of Data	Remarks
1954, Aug.25-31 ("Carol")	A	(2)(3) (4)	Second most damaging storm to hit Conn.coast. Crossed east end of Long Island, moving north. Surge of nearly 6 feet caused flooding at Stamford.
1954, Sept. 6-11	B	(2)(3)	Passed over Cape Cod, heading northeast. High seas, minor damage from wind.
1955, Aug. 10-19 ("Diane")	B	(2)(3)	Passed just south of Long Island and about over Nantucket. Brought record rainfall to many areas of Connecticut; heavy flood damages in river valleys; no tidal-flood damage along coast.

Notes

(1) The following assigned categories pertain to the effect of a hurricane on the coast of Connecticut.
A: Caused tidal flooding.
B: Caused damage from wind or rainfall.
C: Threatened area; no damage.

(2) "Hurricanes - Their Nature and History," by I.R. Tannehill (1956).

(3) Local newspaper accounts, histories, etc.

(4) Material furnished by U.S. Weather Bureau.

C-3. DESCRIPTIONS

Brief descriptions of type "A" and type "B" hurricanes experienced along the Connecticut coast since 1770, as recorded by historians and as reported in newspaper accounts and other records, are given below. Also included are descriptions of four severe hurricanes (Category "A") that are reported to have struck Rhode Island and Massachusetts prior to 1770 but for which no accounts have been found regarding their effect on Connecticut coastal areas.

a. 15 August 1635. From: "Of Plymouth Plantation, 1620-1647," by William Bradford.

"This year the 14 or 15 of August (being Saturday) was such a mighty storm of wind and rain, as none living in these parts either English or Indian, ever saw, being like (for the time it continued) to those Hauricanes and Tuffons that writers make mention of in the Indies. It began in the morning, a little before day, and grew not by degrees, but came with violence in the beginning to the great amazement of many. It blew down sundry 211 houses, and uncovered others; divers vessels were lost at sea, and more in danger. It caused the sea to swell (to southward of this place) above 20 feet, right up and down, and made many of the Indians to climb into trees for their safety; it took off the board roof of a house which belonged to this plantation at Manamet, and floated it to another place, the posts still standing in the ground; and if it had continued long without the shifting of the wind, it is like it would have drowned some part of the country. It blew down many hundred thousands of trees, turning up the stronger by the roots, and breaking the higher pine trees off in the middle, and the tall young oaks and walnut trees of good bigness were wound like a withe, very strange and fearful to behold. It began in the southeast and parted toward the south and east, and veered sundry ways; but the greatest force of it here was from the former quarters. It continued not (in the extreme) above 5 or 6 hours, but the violence began to abate. The signs and marks of it will remain this 100 years in these parts where it was sorest. The moon suffered a great eclipse in the second night after it."

From: "The History of New England from 1630 to 1649," by John Winthrop.

"...This tempest was not so far as Cape Sable, but to the south more violent, and made a double tide all that coast...

"The tide rose at Narragansett fourteen feet higher than ordinary and drowned 8 Indians flying from their wigwams."

b. 3 August 1638. From: "The History of New England from 1630 to 1649," by John Winthrop.

> "In the night was a very great tempest or hiracana at S.W. which drave a ship on ground at Charlestown, and brake down the windmill there, and did much other damage. It flowed twice in 6 hours and about Narragansett it raised the tide 14 to 15 feet above the ordinary spring tides upright."

c. 30 October 1723. From: "The Boston News-Letter, No. 1033. From Thursday November 27, to Thursday November 14, 1723."

> "Rhode Island, November 1.....
> "....On Wednesday last we had here a very great South East storm of Wind & Rain, and a very high Tide, a Foot higher than ever was known before, which has broken & carried away several of our Wharffs, and drove some vessels ashore from their anchors and has done considerable damage in Warehouses and Cellars, to dry goods, and other merchandize: the Loss is computed to some thousand pounds..."

d. 24 October 1761. From: "The Boston News-Letter No. 2991. Thursday, October 29, 1761."

> "Last Friday evening between 8 and 9 o'clock came on the severest N.E. Storm of Wind and Rain that has been known here for 30 Years past, and continued 'till between 2 and three o'clock next Morning;...Five or six Vessels were drove ashore at Providence in Rhode Island Government, and greatly damag'd, and it being high Water there it got into the Stores and Cellars and damag'd Sugars &c. to the amount of 12 or 15,000 (pounds) their Currency; it has also entirely carried away the great Bridge at that Place. - On both roads East and West, so far as we have heard, the Roofs of Houses, Tops of Barns, and Fences, have been blown down, and it is said Thousands of trees have been torn up by the Roots by the violence of the above storm, and we fear we shall hear melancholy Accounts of Damage done at Sea."

From: "The Newport Mercury."

"On Friday last came a terrible storm from the Northeast, which continued increasing with a very heavy rain, and did not abate till after 2 in the morning. The violence of the wind broke off part of the steeple of Trinity Church. Several persons sustained considerable loss in their sugar, salt, etc. by the prodigious rise of tide, which flowed into their stores and cellars. Many of the ships in the harbor were driven ashore from the wharves and their moorings, but without any considerable damage except to two ships. Sad havoc has been made with the lumber and wood on the wharves, great quantities of fence blown and numbers of trees torn up by the roots. People hardly thought themselves safe in their own houses, for a more violent storm has scarce ever been known here."

e. 19-20 October 1770. (Type "B"). "History of the State of Rhode Island", by Samuel Greene Arnold.

"A violent storm again blew down a part of the spire of Trinity Church at Newport and caused an immense loss of life and property along the coast. Newport suffered very severely in this gale."

From: "The Connecticut Journal", November 21, 1770.

"New London, Oct. 26.

"On Friday Night and part of the next Day we had a very Severe Storm of Wind and Rain From the N.E. by which two Vessels were drove ashore in this Harbor but received little or no damage."

f. 19 September 1787. (Type "B"). From the diary of William Wheeler in "Black Rock, Seaport of Old Fairfield, Connecticut 1699-1870."

"Line storm. A mill at Stamford carried off whole and Norwalk bridge floted."

g. 19 August 1788. (Type "A"). From the diary of William Wheeler in: "Black Rock, Seaport of Old Fairfield, Connecticut 1699-1870."

> "The hardest gale that has been for many years--at 1 o'clock a Sloop & Schooner went on shore---. The Gale reached 100 miles up country, in some places shifting from SE to NW & twisting of trees 9 inches in diameter--it moved Carson's house about 6 feet."

From: "The New-Haven Gazette and The Connecticut Magazine," Thursday, August 21, 1788.

> "New Haven.
>
> "Last Tuesday morning came on a violent gale of wind from the South, which at about one o'clock P.M. veered to S.S.W. and blew a perfect hurricane.
>
> "Several vessels were driven ashore and very material damage is done to the long Wharf...We expect to hear of much damage done at sea and in the harbours on our coast..."

From: "The Connecticut Courant and Weekly Intelligence," Monday, August 25, 1788.

> "New Haven, Aug. 20
>
> "Yesterday we had a violent gale of wind, the height of which was from the S.E. about one o'clock. Though the tide was not full as has been frequent in easterly storms, considerable damage was done to the Long-Wharf by the violence of the waves and several vessels parted their masts, but the shipping received no material damage. The Indian corn is much injured and the trees stripped of their fruit and some apple trees blown down."

h. 9-10 October 1804. (Type "B"). From: "The Connecticut Courant," (October 17).

> "The partial and summary accounts which have been received from the neighboring towns, though they afford no particulars of the effects of the late gale, sufficiently evince the widespread destruction which has been experienced by it. In all most every direction the fruit and other trees have been generally blown down, the fences destroyed and much damage done by the heavy rain, which fell during the storm."

i. 18-24 September 1815. (Type "A"). From: "Connecticut Herald," (New Haven) September 26.

"The storm.--On Friday night and Saturday morning last a severe storm of wind and rain was experienced in this vicinity...The most material injury sustained here was to Long Wharf, which was entirely inundated by the highest tide known for a great number of years. Everything movable on the wharf was swept away. The water in some of the stores was nearly two feet deep, but no great loss of property took place except in a quantity of rum which was swept from the wharf, several hogshead of which have not yet been recovered..."

From: "The Connecticut Courant," October 4.

"Bridgeport, Sept. 27.

"The late Storm which commenced on Thursday last continued with increasing violence until 11 o'clock on Saturday morning. The wind during the whole time blew a severe gale accompanied with rain from the N.E. and had so much increased the waters in the Sound that the tide, which in ordinary weather would have been full at 2 o'clock and 44 minutes, attained its greatest height at 12 o'clock 30 minutes, and was then near six feet above common flood tides; and had it not fortunately happened that the wind some hours before the tide was at full veered round to the N.W. it must have risen to an alarming height. The oldest inhabitants do not remember so high a tide by nearly one foot. The water through the whole length of Water Street was of sufficient depth for the largest long boat to pass loaded with passengers. Considerable damage has been sustained in the stores along the shore by the destruction of salt, grain and other bulky articles that could not speedily be removed.

From: "Connecticut Herald," (New Haven), October 5, 1815.

"The late storm has done incalculable damage to roads and bridges, especially on the sea coast, where the tides assisted its destructive power. No mail from Boston has arrived since Saturday last, undoubtedly owing to the road being damaged, and the bridges carried away. An old

citizen of New-Haven who has been particularly attentive to the subject has informed us that forty-five years ago there was a remarkable high tide in this town which did not, however, rise as high by four inches, as the one on Saturday last.--Had not the wind, two hours and a half before high water, suddenly shifted to the westward, it is impossible to tell what damage might have been sustained by inhabitants on the Sound."

j. 1-4 September 1821. (Type "A") From: "Connecticut Herald,"(New Haven), Tuesday, September 11.

"We were visited in the evening of the 3d inst. by a toronado almost unexampled in this latitude. The gale commenced at S.E. about 6 o'clock but was most violent from 8 - 10, the wind then varying from S.S.E. to S.W.--nearly all the vessels in the harbor were driven by the force of the storm, and are more or less damaged...Fortunately at the height of the gale it was time of low water; otherwise, damage to shipping, wharves, stores &c, must have been incalculable...The rafters and gable end of a brock store on the wharf... were blown down... part of the roof of Mr. Thomas Hunt's dwelling in Water St. was torn off...scarcely a street was exempted from fallen chimnies and fences. Several trees were upturned by the roots...the leaves of most of which remain are changed to a singular dark brown hue.

"Part of the first bridge on the pier was carried away by the driving of a sloop, who struck upon her stem.

"At Bridgeport, several buildings were blown down or unroofed...Almost all the vessels in port were driven ashore, but without much injury.

* * *

"New London, September 5.

"Severe Gale. --On Monday night last we experienced a severe gale from the South-East. It commenced about 7 in the evening, and lasted until midnight. The tide rose several feet above its

ordinary level and some damage was done to our wharves and boats..."

From: "Black Rock, Seaport of Old Fairfield, Connecticut, 1699-1870."

> "A tremendous gale of wind E & SE from 6 to 11 in the evening passed over this place--tore down many...trees...every vessel went ashore in this harbor--A sloop dismasted in the sound and the lighthouse laid flat. The hardest gale ever remembered.
>
> "The leaves of the trees as in 1788 are turned brown...small limbs of trees blew thirty rods-- there was a continual roaring like thunder..."

k. 3-6 October 1841. (Type "B"). From: "Hartford Daily Courant," Tuesday, October 5.

> "Severe Storm-- We have been visited by a most remarkable storm--the like of which, so early in the season, on account of its severity and continuance, is not remembered by our oldest inhabitants. On Saturday night it commenced raining, the wind from the northeast, and continued without intermission, intermingled a part of the time with snow and accompanied by wind until sometime yesterday afternoon. During a part of Sunday night, the wind blew a perfect hurricane, and the rain came down in torrents... Many valuable fruit and ornamental trees have been prostrated or stripped of their limbs... as the storm undoubtedly extended along the coast, we may expect to hear of damage from that quarter."

l. 29-30 October 1866. (Type "B"). From: "Hartford Daily Courant," October 31.

> "One of the hardest storms of the season prevailed on Monday and continued through yesterday. It was a regular southeaster-- one of those violent storms that often haunt us at this season of the year...The wind prostrated the lines between New Haven and New York and at other places east and south. The steamer Granite State left

New York at the usual hour on Monday and met with rough weather on the Sound..."

m. 8 September 1869. (Type "A"). From: "Norwich Morning Bulletin," September 12, 1869.

"Storm (at Mystic, Conn.) worst since 1815. Came at low water and the tide, though rising higher that it has for 2 or 3 years, did less damage that it otherwise would have done. Had it occurred at highwater, the bridge and a large part of Mystic would have been submerged. The tide rose at the rate of an inch a minute, walling up a foot high where it struck the spiles at the bridge."

n. 18-24 October 1878. (Type "A"). From: "The Daily Standard," Bridgeport, October 23, 1878.

"A section of the fence...opposite the depot blew down this morning.

"A portion of the bulletin board corner High and Main Streets blew down this morning. Limbs were broken off the trees in all sections of the city.

"The storm last night and this morning drove a number of small boats ashore below the Naugatuck dock and their owners turned out and dragged them beyond reach of the waves...

"The sea held high carnival at Sea Side Park this morning, and a wilderness of rolling white caps and tempest of dashing spray bore witness to the disturbed mood of the waters, angered by the howling winds..."

From: "Greenwich Observer," October 24, 1878.

"....The storm yesterday was very severe and the shipping in our harbor was roughly tossed. The tide rose to a remarkable degree..."

From: "The Daily Standard," Bridgeport, October 24, 1878.

"New Haven, Oct. 23d,--The steamer John Bramhall, Captain Pollard, from this city, ashore on Little Cull Island, has gone to pieces in the gale."

o. 16-20 August 1879. (Type "B"). From: "Stamford Herald," (Weekly) August 20.

"---From a test made at Waterside the rainfall during the late storm was found to be 8 inches. On Monday from 7 a.m. till 7 p.m. a little over 4½ inches fell.

"A more soaking continuous and persistent rainstorm we have seldom experienced in August... corn has suffered under the infliction of so much rain and wind..."

p. 1-13 September 1889. (Type "A"). From: "The Greenwich News," Friday, September 13.

"The furious northeaster which has been raging along the Atlantic Coast for the past few days is one of the severest storms known in this vicinity for years, and one of the most destructive to property. Ever since Tuesday when the storm reached here from the Atlantic, it has blown a gale, mostly from the northeast, accompanied nearly all of the time by rain.

"The greatest force of the storm has been felt along the coastline...small craft along the shore have suffered severely...

"Greenwich has suffered comparatively little from the storm. A few trees have been blown down and the roads have been damaged more or less, but beyond this there was scarcely any damage done. On Tuesday there was a very high tide in the harbor and at one time part of the steamboat dock was under water..the only loss reported along the shore are one or two row boats."

* * *

"The schooner Annie Jacobs from New Haven... was beached on Mansuring Island during the storm Tuesday night."

From: "The Greenwich Opinion," September 20.

"The crib dock which Mr. J.D. Barrett has erected on his property at Belle Haven was washed away by last week's storm.

q. 13-26 August 1893. (Type "A") From: "Stamford Advocate," August 24.

> "One of the most severe storms of wind and rain ever experienced in this locality started last night and continued increasing in force until this forenoon. The evidences of its severity were to be seen on every hand..streets washed out and flooded, buildings damaged...
>
> "...Every boat in the harbor was adrift... The tide rose higher than has been known for some time. All the streets in the vicinity of Waterside were impassable, the water coming up over the meadows to the foot of Atlantic Street...
>
> "The scene in the lower harbor at high tide this morning was a wild one...On the whole the craft in the lower harbor escaped well, much better probably than they would have done had a gale of equal force come in from the southwest."

r. 29 August 1893. (Type "A") From: "The Columbian Weekly Register," (New Haven), Thursday, August 31.

> "Early this morning the wind blew 50 miles an hour, breaking all previous records...Late last night the barometer recorded 29.98, but it was only 29.38 early this morning...
>
> "The waves swept in with terrible fury all along Savin Rock shore. They had full play at the docks made of logs and boards and stone. When the tide was high, about 8 o'clock, the water came up over Beach Street and threatened to enter the handsome shore cottages that front the harbor from Skeele's pavilion to O'Connell's hotel on the Rock...mud from the street was picked up by the spray and spattered on the windows...
>
> "The waves leaped into the air 20 or 30 feet at a time...
>
> "The waves were...tumbling upon the street in front of the Surf House and were making their way in to the ground floor of the hotel. The tide was at its height and soon after began to

recede; with the falling of the tide the danger that threatened the house in being overflowed with a part of Long Island Sound subsided...The dock or wharf front of logs and boards was partially demolished. Mr. Cox's damage will be at least $500.00...

"But the storm's destructive power was felt in dead earnest at Stewart's pavilion and thereabouts in front of Sea View hotel. The Sound took one bite out of the solid earth in Front of Stewart's that was 75 feet long and 10 and 20 feet wide in some places...It washed away some of the bathing houses...

"The wind was tearing over Savin Rock at a 60-mile gait."

s. 3-11 September 1896. (Type "B") From: "Greenwich Graphic," September 25.

"Between five and six o'clock on Saturday night it rained and blew in a way that caused many people to be frightened. It was the most severe storm we have had this summer...From William St. to Putnam Ave. it was impassable after the storm. The wind twisted the great trees and broke them as though they were pipe stems...The rain came down almost in torrents and on Greenwich Avenue the water flowed in the gutters like the stream from a large brook."

t. 9-19 September 1901. (Type "B") From: "The Bridgeport Standard," Wednesday, September 11.

"Last night's rain had a disastrous effect on property on Goodsell and Thompson Streets because of the inadequacy of the trunk sewer to carry off the extremely heavy precipitation...

"The storm during last night caused two serious washouts under the tracks of the Shelton division of the Connecticut Railway & Lighting Company's system..."

From: "The Bridgeport Standard," Thursday, September 12.

"In consequence of the heavy fall of rain last evening, the top dressing was washed from Congress, Arch, High, Fulton and Franklin streets into the sewers on Main Street...trolley cars were stalled at various points of the road because of small washouts...

"According to the records of William H. Jennings, the voluntary weather observer, last night's precipitation was one inch and twenty-four one-hundredths."

u. 13-17 September 1903. (Type "A") From: "The Bridgeport Daily Standard, September 17.

"Very strong winds and rain unroofed houses, felled or uprooted trees.

"...a casual survey of the damage along the waterfront shows that it will run into the thousands...

"At the Bridgeport Yacht Club in the Black Rock harbor there was damage galore, and but for the active work of the yachtsmen there would have been several fine yachts totally wrecked.

"Although the waves were very high the water did comparatively little damage... no water ever reached the roadway although everybody was completely drenched with the spray which rose in a long continuous, heavy white cloud the whole length of the sea wall."

* * *

"New Haven, September 17. Wind, rain and a phenomenally high tide combined to make the damage in and about New Haven very extensive.

"The bathing pavilion in the rear of Mrs. Albert Wintter's residence at 313 Seaview Avenue was blown in the water."

From: "The Daily Advocate," Stamford, September 16.

"The storm which is raging all over this section struck Stamford with a vengeance at noon

today and inside of an hour it had shaped itself into what old-timers say, is the swiftest easterly storm experienced for twenty years or more...

"On the east shore of Shippan, the storm was felt with great severity, and the same is true of Sound Beach where there are a number of summer cottages near the shore.

"The wind blew great guns...rain fell in veritable sheets. On exposed corners this was particularly noticeable, the pavements being under a constant wash of water...The wind came from the east and blew at from 75 to 80 miles an hour."

v. 8-16 September 1904. (Type "B"). From: "New Haven Evening Register," September 15.

"At one time early this morning, shortly after midnight the wind being then at the southwest, blew at the rate of 40 miles an hour.... During the entire progress of the storm in New Haven 3.96 inches of rain fell...At Casey Beach, during the early part of the storm, the shore was heavily lashed by angry waves and for a time it seemed as though some of the lighter of the houses would be thrown from their foundations. Then the wind shifted and blew offshore and the water smoothened...Trees were uprooted and oyster beds damaged by the winds..."

w. 9-14 November 1904. (Type "B") From: "New Haven Evening Register, November 14.

"Here in New Haven the wind in yesterday's gale blew as high as 50 miles an hour. Many telephone and telegram wires were prostrated and there was some light wreckage about the harbor..."

x. 12-22 July 1916. (Type "B"). From: "The New Haven Journal Courier," July 14, 1916.

"During the course of the storm the wind and rain beat so hard upon Murphy's Pier at Savin Rock that part of the structure collapsed...

"Street and road flooding caused by deluge... and quite a little damage done to flooded cellars of business places, especially in the center of the city.

y. 27 Sept. - 1 Oct. 1920. (Type "A") From: "The Daily Advocate, Stamford, October 1.

"The wind attained a velocity of 60 miles an hour, and it roared along the shorefront in an alarming manner, but did no great actual damage there. It veered from south by east, late in the afternoon to a more southerly direction as the night wore on. It greatest velocity was attained about midnight. That was sufficient to rock some houses on their foundations.

"Boats were torn from their moorings and trees were blown down."

* * *

"Norwalk, Oct. 1. --Last night's storm here was the worst in years, doing damage along the Sound shore. The tide reached a record height at 1 a.m., the water covering the roads and wrecking a number of cottages at Belle Island...12 small boats were carried ashore and wrecked...and much damage done by the wind."

"New Haven, Oct. 1. Thousands of dollars of damage was done along the Sound shore last night by one of the worst storms in several years. Driven by a gale which exceeded 40 miles from the southeast and accompanied by a high tide. The waves rolled mountain high against the beach during the night, the tide reaching a record height about midnight. Many boats were washed ashore, cottages, piers and breakwaters being partially wrecked.

"At the Weather Bureau this morning it was stated that the wind reached a velocity of 42 miles at the height of the storm. A total rainfall yesterday and last night of 2.51 inches was recorded."

z. 16-27 August 1924. (Type "B"). From: "Stamford Sentinel, August 27.

"Nothing like the devastation of felled wires, cables and poles in the eastern part of the state ever has been experienced by the telephone people..."

* * *

"New Haven, Conn. Aug. 27.---With approximately 6,000 telephones out of commission in the territory east of Saybrook, a section of the state severely hit by a juvenile toronado late yesterday afternoon the Southern New England Telephone Company suffered more damage than...in a great many years..."

aa. 22 September - 4 October 1929. (Type "A") From: "New Haven Journal-Courier," October 3.

"Damage while will probably total thousands of dollars was done yesterday along west shore in Milford by the lashing northeaster which swept northward from the Caribbean..its ferocity had been largely spent by the time it had reached the shores of Long Island Sound...

"The largest damage reported from along the shore yesterday came from Silver Beach in Milford where the strong northeasterly and easterly gale created waves at the high tide hour this morning which tossed one cottage off its foundations...

"The water overflowed the trolley tracks and in some places covered the Milford shore road to a depth of two feet...the storm concentrated its fury on the Milford shore...

"High tides came near flooding street car tracks where they pass close to the water's edge on the shore runs, it was said, but no delays were brought about by this cause.

"Official figures...for total rainfall...of 2.03 inches between 8 p.m.and 8 p.m. yesterday and precipitation for the 12 hours after 9 a.m. yesterday being 1.30 inch.

"The wind velocity at both 8 a.m. and 8 p.m. was 12 miles per hour atop the post office building, but reports had velocities of 25 miles an hour at Milford."

bb. 24 August 1933. (Type "B"). From: "Daily News-Graphic," (Greenwich) August 24.

".....HURRICANE'S EDGE WHIPE ACROSS TOWN.
".....the gale swept the madly rolling Sound. A total rainfall for the week of 3.71 inches was reported by the Water Company here, enough to flood a less undulating country."

From: "Bridgeport Post," August 24.

"GALE TEARS DOWN TREES...AS WAVES POUND SHORE; DAMAGE ALONG COAST SET AT MILLIONS

".....the storm accompanied by a driving rain, whipped the Sound into a fury, halted shipping and threatened many shore cottages as it gathered velocity with the rising tide early this morning...

"....Little damage was reported...on Long Island Sound side of town although exceptionally high tides and turbulent seas were reported."

cc. 5-9 September 1934. (Type "B") From: "Stamford Advocate," September 10.
".....Saturday night's furious storm did thousands of dollars' damages.

"The storm lashed at the New England coast, battering the Connecticut area with such fury that it left a trail of havoc, especially in Stamford and the surrounding towns...Trees were uprooted... cellars and streets flooded...."

From: "Daily News-Graphic," (Greenwich) September 10.

"HIGHWAYS WASHED OUT BY HEAVY RAINFALL

"...an 85-mile-an-hour gale and nearly three inches of rain...Saturday night...felled trees and flooded cellars in all parts of town."

dd. 8-26 September 1936. (Type "B"). From: "Daily News-Graphic," (Greenwich,) September 19.

"HURRICANE DRIVEN GALES STREW GREENWICH WITH DEBRIS

"...trees uprooted...boats torn from their moorings in Greenwich Harbor, but scattered damage was not

of record proportions...

"The gales, driving toward the Sound, came in the backlash of the southern hurricane that roared up the Atlantic coast...

"Rainfall varied from two inches in the vicinity of Greenwich Water Company's Putnam lake filter plant to 2.76 in central Greenwich nearer Long Island Sound...

"Stamford police reported that Stamford was 'very lucky', no serious damage. Wires and branches were reported down in several places."

From: "Bridgeport Post," September 19.

"A tree-toppling gale...swept through Fairfield County last night and early today at a velocity of 45 miles an hour...wrecking damage of thousands of dollars. It was accompanied by torrential sheets of rain."

From: "Stamford Advocate," September 19.

"A howling wind, which drove before it a heavy rain, swept over Stamford last night and early today, disrupting telephone and electrical service in the town and city...

"...the rainfall, recorded at two inches, continued at intervals...

"...no damage to shipping...Several boats dragged from their moorings."

ee. 16-22 September 1938. (Type "A") From: "Stamford Advocate, September 22.

"STAMFORD'S WORST STORM

"Caught in the path of a 50 to 90-mile-an-hour tropical hurricane, Stamford experienced one of the most devasting storms in its history as the terrific wind and tidal wave...brought death to one man, drove families from flooded homes and caused a loss through property damage estimated at several hundred thousands dollars.

"...families (were) removed from sections of the South End last night and early this morning after being marooned for hours by water that lapped treacherously against buildings in its eight-foot rise in many streets...

"....trees uprooted by hundreds.'

"The Stamford Division of the Connecticut Power Company issued a statement saying:

"At 7 p.m. the tide in the west branch channel rose with unusual rapidity until it reached its maximum height about one hour before the scheduled high tide. This height was over two feet above the bulkhouse of the Connecticut Power Company's electric plant at its docks on South Street. This tremendous tide poured over the dykes and bulkheads and flooded the South End...Sandbags were in use and pumps were adequate to take care of any reasonably unusual condition, but when the tide came up underneath all of the equipment and broke into and flooded the electric station, operation could only be continued until serious difficulty was encountered on one of the generating units...'

"Water...under railroad bridges and along Canal, State and Jefferson Streets, Magee Ave., Shippan Avenue, cut Shippan Point off from the rest of the city.... Some residents in this section of the city reported a height of two inches (of water) on their first floors.

"Thousands of dollars damage was reported along the waterfront as the tidal wave lifted valuable yachts and other craft and hurled them against each other at their moorings and against docks and rock-covered shores...

"The dock and pier at the Stamford Yacht Club were washed away, leaving only the piles standing...

GREENWICH

"The highest tide ever seen in the Sound, the heaviest rain on record, and a wind reaching as high as 100 miles an hour united forces for an attack on Greenwich yesterday...leaving in their wake property damage which may amount to hundreds of thousands of dollars.

"Almost a thousand volunteer workers battled for hours to snatch those who could be saved from flood and tide water...

"The southern half of Old Greenwich was hardest hit with the Sound climbing its shore to flood under several feet of water most of the roads, all the cellars and some of the first floors.

"Along the waterfront Grace Island was completely under water... The Indian Harbor Yacht Club basement was awash...

"Unofficial weatherman Robert Wilcox stated.. that...since last Saturday 8.80 inches of rain has poured out of the skies.

"Cos Cob Fire Company was driven out of the fire house by the rising tide."

* * *

DARIEN

"Darien Hard Hit

"Pratt Island residence swept away.

"Several homes along the shorefront have completely disappeared...

"The $30,000 town bathing pavilion at the public beach was twisted and when the piers were swept from underneath, one-half of it dropped into the Sound."

ff. 9-15 September 1944. (Type "A"). From: "Stamford Advocate," September 15.

"Following almost the exact path of the disastrous storm of 1938, the savage Atlantic coast hurricane lashed Stamford for hours last night as winds ranging in velocity from 60 to 80 miles an hour felled trees and electric power lines, blocking highways, disrupting utilities and wartime factory schedules, and causing other widespread damage. Sheets of rain flooded streets and in the South End area near flood conditions prevailed...

"The Harbor Patrol reported today a peculiar phenomenon in connection with the rising waters as observed along the docks on Water Street. The tide had continued to rise until approximately 11 p.m. when it turned and started to fall. After the tide had dropped approximately one foot it turned aroung and rose again to the earlier height. At 11:50 without any noticeable change in the wind and after the rain had stopped the level of the water rose another foot in five minutes carrying the high water mark up to the middle of Water St.

"It receded approximately 10 inches and at 12:05 a.m. returned a second time to the middle of Water St. This same flow and recession occurred a third time at 12:30 a.m. and a fourth time at 1 a.m. The fourth and final step of what was undoubtedly a tidal wave was the highest of them all. By the time of the fourth and highest step the wind had subsided considerably...

"There was four feet of water in the main street at Savin Rock, East Haven amusement park on Long Island Sound, but the buildings there withstood the storm's fury, although the structure ...blew down in 1938."

gg. 25-31 August 1954. (Type "A") From: Stamford Advocate," August 31.

"Though high tide was not due until 1:53 this afternoon, residents of the South End reported that the streets were starting to flood by 1, and that water was coming down lower Pacific Street 'like a river.'"

From: "Stamford Advocate," September 1.

"The expected northwest wind that would have kept back some of the force of the water borne in on the high tide on Tuesday failed to materialize and the Sound moved in and took over large portions of the land.

"Residents of Shippan were marooned in their homes when even the high-wheeled fire trucks were unable to drive into the area until late in the afternoon.

"The first phase of the storm saw trees blown over, often taking electric and telephone wires with them. Cars were damaged by falling trees...

"When the storm was over, about noon, and a bright sun was shining in a blue sky--that was when the floods came.

"Most of the residents in the low areas, apparently confident that the worst had passed, stayed in their homes. Suddenly, the rising waters swept over the retaining walls and shot over the streets, yards and sidewalks. Cellars were soon filled...

"...Soon after 1 p.m. the water was so high on Shippan Avenue, extending up beyond the entrance to Cummings Park, that few persons would attempt to drive down the avenue.

"The water came up within about 10 feet of the Stamford Yacht Club main building. It flooded into the pool and the bathhouses...

"The lower part of Shippan was the heaviest hit... Ocean Dr. East and Ocean Drive West presenting the picture of small lakes covering lawns and entering cellars.

"The South End of Stamford continued to resemble a scene in Venice, Italy today with streets flooded by two to three feet of water. (In) Dyke La. the depth of water was sufficient to permit transportation by outboard motor although the flood level had receded two feet from the high-water mark of yesterday recorded on the walls of most of the buildings.

"At noon waters still covered the Kiddie Carnival and parts of the Starlite Drive-in Theatre on Shippan Avenue. The Drive-In Theatre was completely under water Tuesday afternoon. The manager...reported it was 8 feet at the box office and up to 6 feet deep in other parts."

"The Yale & Towne plant was surrounded with water and some employees who went out to lunch were not able to return to the building... Only maintenance crews and supervisory personnel were able to work today...

"Pitney Bowes had some flooding in the southeast corner where the screw machine and punchpile machines are located...

"The courtyard of Pitney Bowes was flooded and some of the storage space on Ludlow Street was similarly affected...The water also flooded over Weed Ave. and at one point up to Mathers St. to the intersection of Cambridge Rd."

hh. 9-11 September 1954. (Type "B") "The Day" (New London).
Sept. 13.

"She (hurricane) stabbed the area for 8 hours Saturday...

"She deposited more than 6 inches of rain - a record - and caused floods in areas where brooks overflowed or the catch basins couldn't contain the water.

"She might have done more damage, but she spent most of her fury in this area at a time when the tide was at low ebb.

"The Groton filtration plant in Poquonoc Bridge reported a fall of 6.15 inches from midnight Friday to 3:00 p.m. Saturday, a record for a 14 hour period...

"The wind was reported at 75 miles an hour."

C-4. HURRICANE TRACKS

The tracks of four notable hurricanes causing tidal flooding and serious damages along the Connecticut coast, namely, those of September 1815, September 1938, September 1944, and August 1954, are shown on Plate C-1. The path of Hurricane "Diane," (1955) a storm which brought record rainfall to many areas in southern New England, is also shown on the plate.

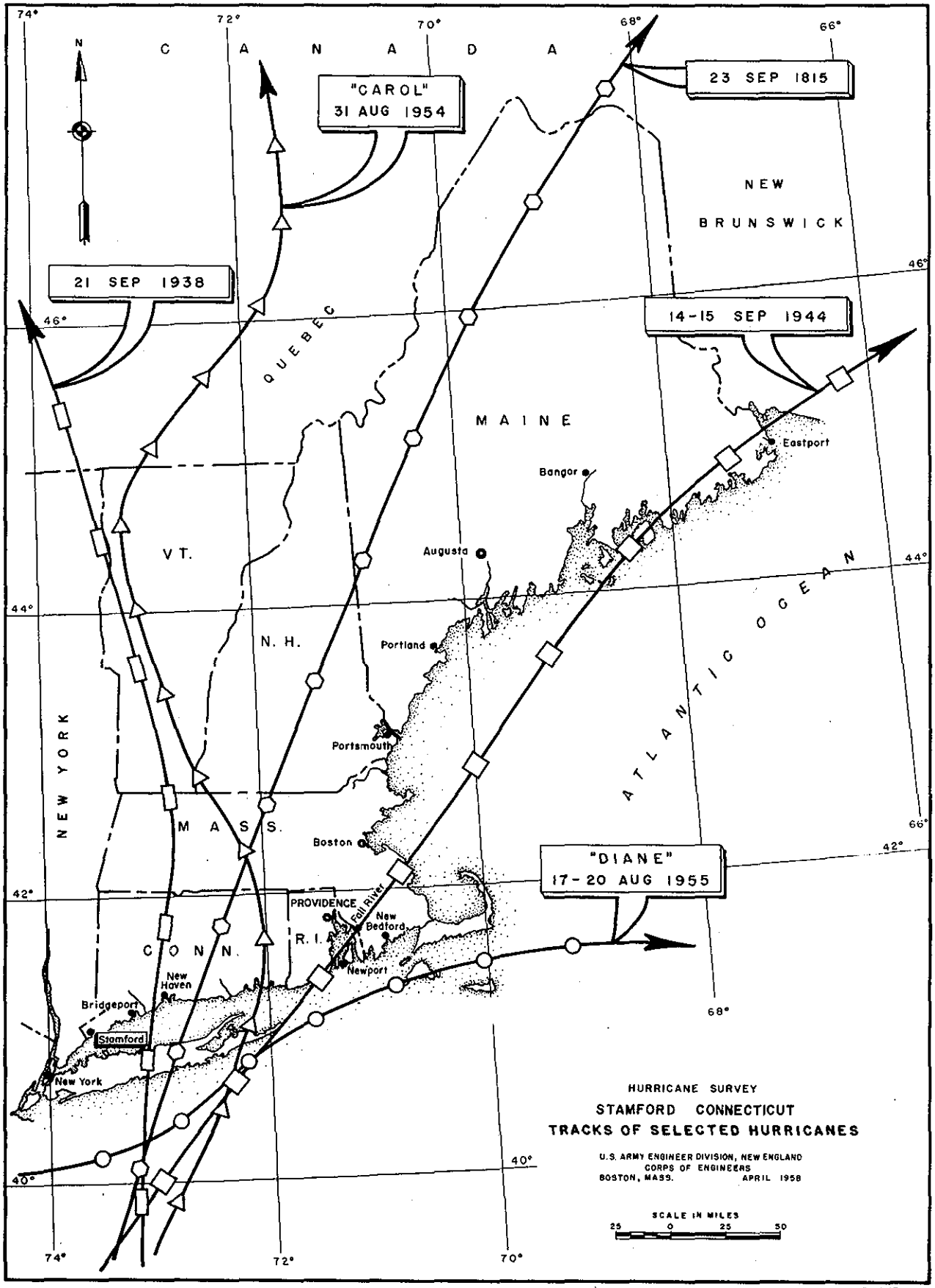

74°
72°
70°
68°
66°
N
C A N A D A
"CAROL"
31 AUG 1954
23 SEP 1815
NEW
BRUNSWICK
21 SEP 1938
46°
14-15 SEP 1944
QUEBEC
MAINE
Eastport
Bangor
VT.
Augusta
44°
ATLANTIC OCEAN
N. H.
Portland
NEW YORK
Portsmouth
MASS.
Boston
"DIANE"
17-20 AUG 1955
42°
PROVIDENCE
Fall River
New Bedford
CONN.
R.I.
Newport
New Haven
Bridgeport
Stamford
New York
40°
HURRICANE SURVEY
STAMFORD CONNECTICUT
TRACKS OF SELECTED HURRICANES
U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
BOSTON, MASS.
APRIL 1958
SCALE IN MILES
25 0 25 50

PLATE C-1

APPENDIX D

FLOOD LOSSES AND BENEFITS

APPENDIX D

FLOOD LOSSES AND BENEFITS

GENERAL

D-1. DAMAGE SURVEYS

Damage surveys were made in Stamford in December 1956 and January 1957. These surveys showed that enhancement possibilities existed in several areas of the city where protection was proposed, and enhancement studies were undertaken during the summer of 1957. Essentially, the damage survey was a door-to-door inspection of the hundreds of industrial, commercial, residential, and other properties affected by tidal-flooding in recent hurricanes, and included the collection of other data upon which economic studies of various protection plans could be based. The information obtained included the extent of the areas flooded, descriptions of properties, including changed conditions since the 1954 hurricane, the nature and amount of damages, depths of flooding, high-water references, and relationships between 1954 and previous flood stages. Evaluations of damage were generally furnished by tenants or property owners and, if unreasonable, were modified by the investigators. Sampling methods were often used where properties of the same general type were subject to the same depth of flooding. Data on damages to public property, highways, utilities, and railroads were obtained from central sources and applied to field information. The survey area included the entire shore line of Stamford from Peck Point eastward to the head of Holly Pond.

Sufficient data were obtained to derive losses at the 1954 flood stage, and a stage 3 feet higher. The stage of zero damage, that is, the stage where damage begins, was also determined. This stage was referenced to the 1954 flood level. Losses were also obtained for stages of floor levels and window openings where marked increases in damages occurred.

D-2. LOSS CLASSIFICATION

Flood loss information was recorded by type of loss and by location. The types of losses included were industrial, urban (commercial, residential and public), rural, highway, railroad, and utility. The losses were also recorded by subdivisions, such as city blocks within the flooded area, in order to provide a basis for later use in stage-loss and benefit analyses.

The losses evaluated in the survey were tangible, primary damages. Primary damages comprise the following: (1) physical losses, such as

damage to structures, machinery and stock, and cost of cleanup and repairs, and (2) non-physical losses, such as unrecovered loss of business, wages, or production; increased cost of operation; cost of temporary facilities; and increased cost of shipment of goods into or out of the inundated areas.

The primary loss resulting from physical damage, and a large part of the related non-physical loss, were determined by direct inspection of flooded properties and evaluation of the losses by either the property owners or field investigators, or both. The non-physical portions of the primary loss were often difficult to estimate on the basis of available information. Where this condition existed, the non-physical losses were estimated by utilizing determined relationships between physical and non-physical losses for similar properties in the survey and other areas.

Monetary evaluations were not made of secondary damages or intangible losses. Secondary damages, those incurred outside the immediate flooded area under study, include such items as increased cost of travel and shipment of goods, loss of utilities and transportation facilities, and business losses. Intangible losses include items such as loss of life, hazards to health, and detrimental effects on the national security.

HURRICANE TIDAL-FLOOD DAMAGES

D-3. TIDAL-FLOOD LOSSES

The Stamford area, one of the harder hit areas on the coast of Connecticut in past hurricanes, sustained serious losses in Hurricane "Carol" on 31 August 1954. The hurricane tidal-surge in 1954 occurred nearly coincident with the peak of a gravitational high tide and caused severe flooding of the waterfront areas of Stamford, especially along the main harbor, the two Branches, and Westcott Cove. The destructive tidal-flooding in 1954 rose 6.5 feet above mean high water in Stamford Harbor, reaching a level 8 inches below the record tidal-flood height experienced in 1938. In the survey area (from Peck Point at the Greenwich line to the head of Holly Pond at the Darien line) tidal-flooding caused total damages of over $3,400,000. Over 570 structures suffered flood damages. Damage areas are described in Table D-1 and are shown on Plate D-1.

D-4. TYPE AND DISTRIBUTION OF LOSSES

Industrial concerns with plants located on low ground along the waterfront and in the South End area, between the East and West Branches, were particularly hard hit. Twenty-one companies together suffered losses of nearly $2,100,000, which represents about 60 percent of the

total tidal-flood damage in the city. A tabulation of 1954 experienced tidal-flood losses in Stamford, by damage area and by type, is shown in Table D-1 on the following page.

In Area I, on the west bank of the West Branch and the harbor, tidal-flooding caused damages amounting to $285,000. The major loss in this area was sustained in a residential development, overlooking Davenport Point, where over 20 homes were flooded to an average depth of 1.5 feet on the first floor.

The highly-industrialized area between the West and East Branches, Area II, suffered a loss of nearly $2,500,000 which represents approximately 73 percent of the total 1954 flood loss in Stamford. Four large industrial concerns in this area received the brunt of the $1,800,000 loss sustained jointly by the 11 industrial firms in this area: Yale and Towne Manufacturing Company; Pitney-Bowes, Incorporated; Consolidated Diesel Electric Corporation; and the Amicale Yarns Division of the Manhattan Pacific Corporation. Losses to some 280 residential properties and 70 commercial establishments in this area totaled about $670,000.

Area III, the lowland area between the East Branch and Westcott Cove, sustained damages of nearly $500,000. The Unique Balance Company and three other industrial plants suffered over half of the loss in this area. Approximately 170 dwellings and 30 commercial concerns experienced flooding of basements, with damage to electrical circuits accounting for most of the urban loss. First-floor damage was limited to some 17 buildings which experienced flooding to depths up to 2 feet.

Approximately 50 homes and cottages on Shippan Point, Area IV, sustained flood damages of about $35,000. Six homes were flooded to depths up to 3 feet; basement flooding was experienced in the remaining properties.

Losses in the residential area between Westcott Cove and the head of Holly Pond, Area V, amounted to about $125,000. Approximately 60 houses were inundated by tidal-flooding, of which about 15 dwellings were flooded to depths up to 3 feet on the first floor.

In addition to extensive residential, commercial, and industrial losses in Stamford, damages sustained by craft afloat and by automobiles in the flooded area accounted for considerable losses which were not included in the tabulations of damages, or were included only in part, since information on these losses was meager or unavailable. Available evidence indicates, however, that losses of this nature were substantial in both the 1938 and 1954 hurricanes.

TABLE D-1

EXPERIENCED TIDAL-FLOOD LOSSES

HURRICANE "CAROL", 31 AUGUST 1954

Stamford, Connecticut

Area	Description	Losses in Thousands of Dollars				
		Urban	Rural	Industrial	Highway	Total
I	West bank of West Branch and main harbor	240	25	15	5	285
II	Area between West Branch and East Branch	670	-	1,805	20	2,495
III	Area between East Branch and Westcott Cove	210	-	285	5	490
IV	Shippan Point, below Wallace Street	35	-	-	-	35
V	Area between Westcott Cove and head of Holly Pond	125	-	-	-	125
	Total	1,280	25	2,095	30	3,430

D-5. RECURRING LOSSES

Stage-loss curves, referenced to the 1954 tidal-flood level, have been developed as the basis for economic analysis. These stage-loss curves, prepared from data collected in the recent damage surveys, afford a means of determining the magnitude of recurring losses at any stage of flooding up to a stage 3 feet above that experienced in 1954. The difference between the experienced losses in the flood of 1954 and the recurring losses used in development of the stage-loss relationship reflects economic and physical changes in the area since 1954 as revealed by the damage survey. Recurring stage-loss data for individual properties, referenced to the peak elevations for the 1954 hurricane flood, have been summarized for the areas afforded protection by Plan "E".

A number of primary flood losses, both tangible and intangible, have not been included in the economic analyses of protective measures, even though these losses may be substantial in a given instance of tidal-flooding. Tangible losses in this category are made up of (1) damages to vehicles either underway or parked on the street or in public or commercial parking lots and (2) damages to small craft and vessels afloat at shore facilities, or on the open water, which are subject to an indeterminate combination of wind, waves, and tide. These categories of losses consist of damages to items which are not always present in the same place, at the same time, or in the same quantity. To put losses in this category in perspective for analysis would require a framework of multiple assumptions.

A breakdown of the tidal-flood losses to be anticipated in the flood areas at Stamford and in the areas protected by hurricane Protection Plan "E" in the event of future hurricanes, are shown in Table D-2.

TABLE D-2

RECURRING TIDAL-FLOOD LOSSES

Stamford, Connecticut

Equivalent Hurricane	Equivalent Non-Hurricane Storm	Flood Stage (feet msl)	Losses (1957 prices) Entire Flooded Area	Plan "E" Protected Area
31 Aug 1954	-	10.3	$3,050,000	$2,580,000
14 Sept 1944	-	9.2	620,000	520,000
21 Sept 1938	-	11.0	5,790,000	5,190,000
-	25 Nov 1950	9.5	960,000	810,000
-	7 Nov 1953	9.2	620,000	520,000

The stage-loss relationships found in the Plan "E" protected area at Stamford are shown on Plate D-2.

ANNUAL LOSSES AND BENEFITS

D-6. GENERAL

The total benefit of the plan to control tidal-flooding in Stamford is made up of flood damage prevention benefits, enhancement benefits, and benefits from the elimination of scare costs. The flood damage-prevention benefits are by far the most important. The annual benefits of such nature attributable to hurricane Protection Plan "E" at Stamford have been determined in accordance with standard practice of the Corps of Engineers utilizing stage-loss, stage-frequency, and damage-frequency relationships.

D-7. AVERAGE ANNUAL TIDAL-FLOOD LOSSES

Tidal-flood losses in Stamford have been converted to average annual losses by correlating stage-loss and stage-frequency relationships to derive damage-frequency curves. The stage-frequency curve is based upon the known peak elevations in the hurricanes of 1938 and 1954 and in a number of recent storms, other than hurricanes, and on the estimated stages in other hurricanes and severe storms occurring within the past 142 years.

The stage-loss curve has been combined with the stage-frequency curve to develop a damage-frequency curve which has been plotted with damage as the ordinate and with percent-chance-of-occurrence (the reciprocal of frequency) as the abscissa. See Plate D-2. The area under this damage-frequency curve is a measure of the average annual loss. The average annual loss in Stamford which will be protected by Plan "E" amounts to about $378,000 at a 1957 price level.

D-8. ANNUAL DAMAGE-PREVENTION BENEFITS

Average annual benefits from the prevention of tidal-flood damages have been derived by determining the difference between the average annual losses under present conditions and the average annual losses remaining after construction of the protection plan. The residual damages from the ponding of overtopping and interior runoff during a hurricane or other great storms are negligible. The average annual flood-damage prevention benefits attributable to the plan total about $337,000.

D-9. SCARE COST BENEFITS

In addition to actual tidal-flood damage, significant losses are sustained in areas subject to tidal flooding due to the cost of setting temporary protective measures into operation following the receipt of hurricane warnings. Based on data gathered in the course

of damage surveys in the Stamford area and in other areas subject to tidal-flooding, it is estimated that 25 percent of the commercial establishments and 50 percent of the industrial concerns in the flooded area attempt to minimize their potential losses through temporary preventive measures. The estimated benefits to Plan "E", by eliminating scare costs incurred in a single hurricane warning, amount to $44,000 (1957). Based on a frequency of four hurricane warnings in a 10-year period, the average annual benefit from the elimination of scare costs amounts to $17,000 (1957).

D-10. ENHANCEMENT BENEFITS

A field investigation was made in the summer of 1957 of several areas in Stamford where it appeared that enhancement benefits might result from higher utilization of land in the area protected by Plan "E". These studies found that enhancement benefits would be negligible, except in two areas between the East Branch and Westcott Cove. The enhancement analysis disclosed that annual benefits of $9,000 would be attributable to Plan "E" protection.

In the smaller of these two areas, an urban-renewal area of some 7.5 acres, on the east bank at the head of the East Branch, flood threats hinder the development of land recently reclaimed from substandard residential use. Industrial development would logically follow protection because of proximity to adjoining industrial areas and existing transportation facilities. Utilizing a present land value of $0.75 per square foot, as indicated by recent purchases of comparable land in the area between the East and West Branches, and assuming enhancement at 50 percent, an enhanced value in excess of $100,000 would result from construction of the Plan "E" protection. This value, capitalized at 6 percent, gives an annual enhancement benefit of $6,000.

The second area where enhancement would follow protection is a city-owned, partially developed area of about 10.9 acres at the southern edge of the residential and commercial district between Magee and Shippan Avenues. The State of Connecticut has approved plans for development of the area as a municipal heliport and small airport, and has agreed to contribute approximately one-third of the estimated cost of about $150,000. Construction of hurricane protection works could be expected to speed the development of the heliport facilities and permit greater utilization and expansion of this readily accessible area. The enhancement analysis disclosed that greater utilization of the area, after construction of protective works, would be expected to result in a minimum increase in land value of $0.10 per square foot, or a total enhancement benefit of about $50,000. This increment, capitalized at 6 percent, produces an annual return of approximately $3,000. Thus, an annual enhancement benefit of $9,000 would be derived from enhanced land values in both areas.

D-11. SUMMARY OF BENEFITS

Total annual benefits of $363,000 attributable to the protection provided by Plan "E" include $337,000 from average annual flood-damage prevention benefits, $17,000 from the elimination of scare costs, and $9,000 from land enhancement benefits.

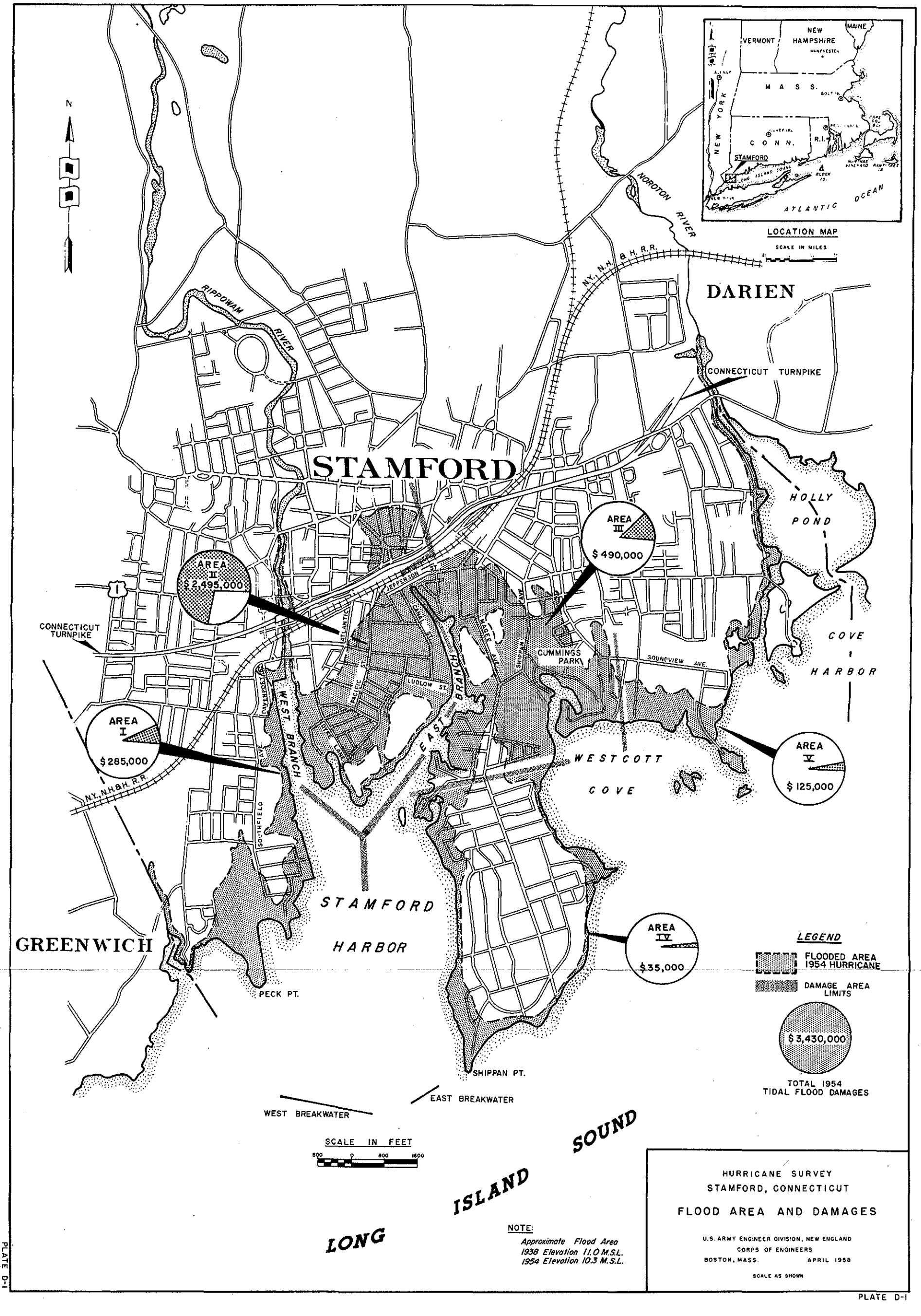
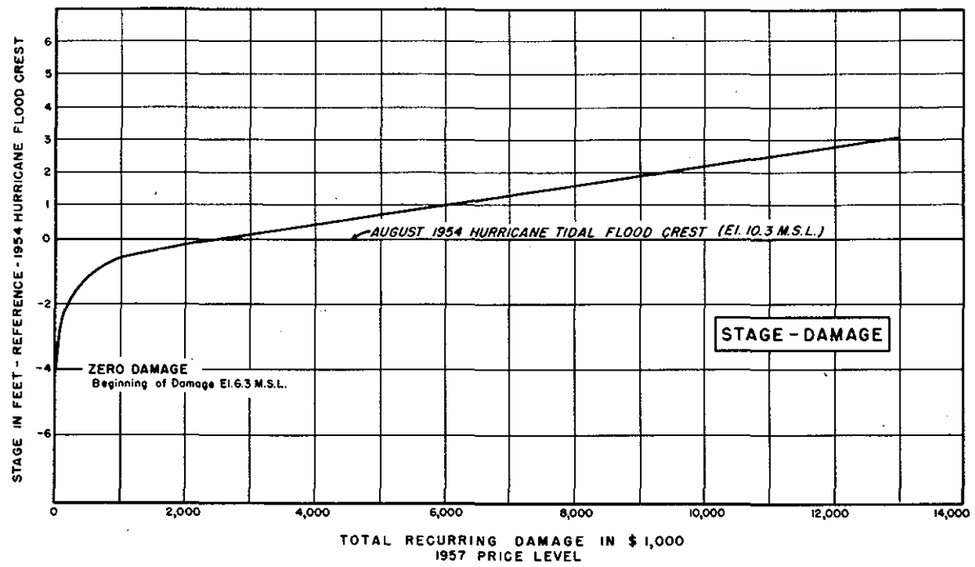
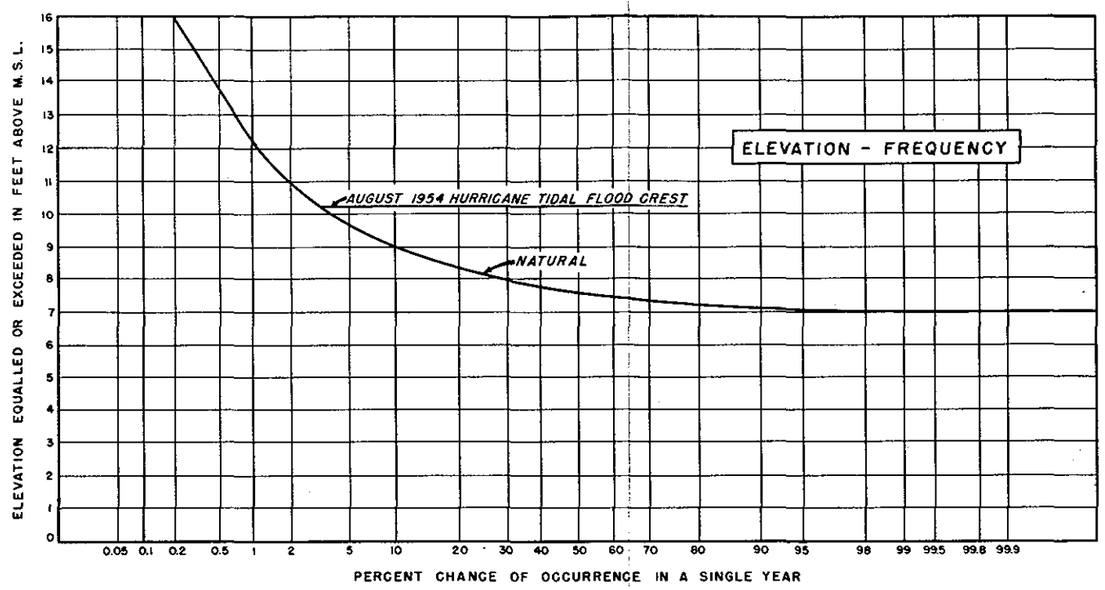
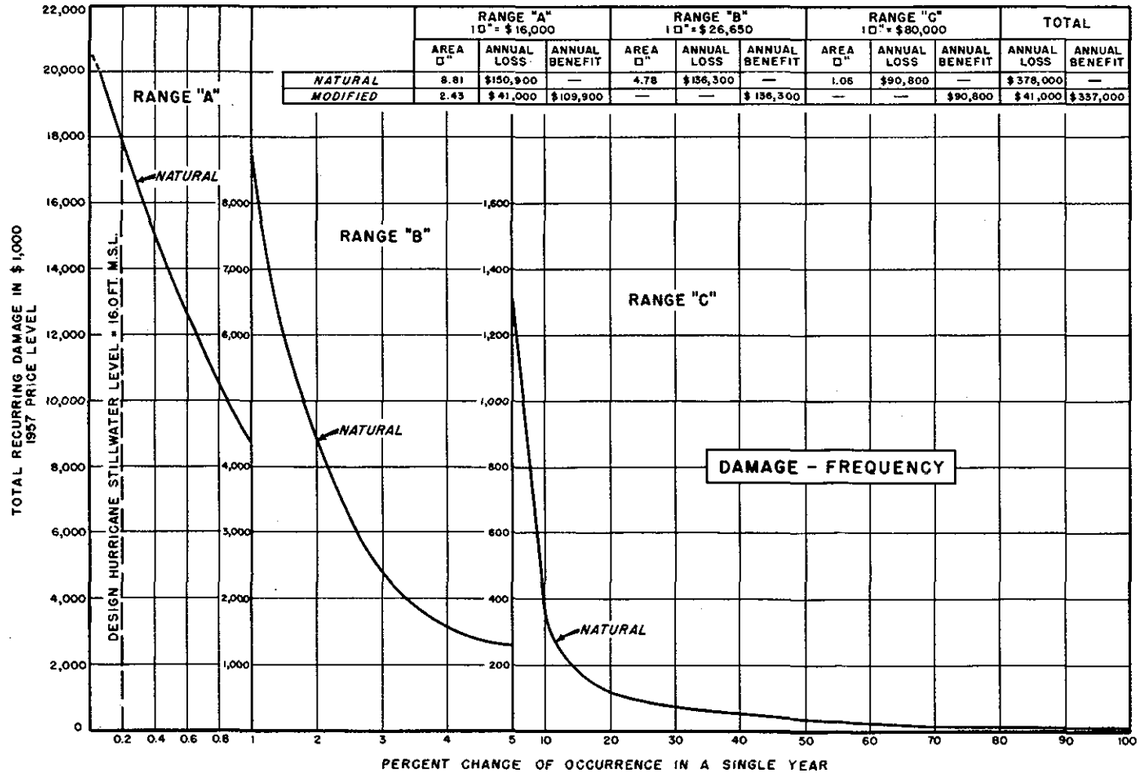

N
RIPPOWAM RIVER
NOROTON RIVER
N.Y., N.H. & H. R.R.
DARIEN
CONNECTICUT TURNPIKE
STAMFORD
HOLLY POND
COVE HARBOR
WEST COTT COVE
CUMMINGS PARK
SOUNDVIEW AVE.
JEFFERSON ST.
ATLANTIC ST.
PACIFIC ST.
CANAL ST.
MAGEE AVE.
SHIPPAN AVE.
LUDLOW ST.
DAVENPORT AVE.
SOUTHFIELD AVE.
WEST BRANCH
EAST BRANCH
N.Y., N.H. & H. R.R.
CONNECTICUT TURNPIKE
AREA I $285,000
AREA II $2,495,000
AREA III $490,000
AREA IV $35,000
AREA V $125,000
GREENWICH
STAMFORD HARBOR
PECK PT.
SHIPPAN PT.
EAST BREAKWATER
WEST BREAKWATER
LONG ISLAND SOUND
LOCATION MAP
SCALE IN MILES
NEW YORK
VERMONT
NEW HAMPSHIRE
MAINE
MASS.
CONN.
R.I.
ATLANTIC OCEAN
LEGEND
FLOODED AREA 1954 HURRICANE
DAMAGE AREA LIMITS
$3,430,000
TOTAL 1954 TIDAL FLOOD DAMAGES
SCALE IN FEET
800 0 800 1600
NOTE:
Approximate Flood Area
1938 Elevation 11.0 M.S.L.
1954 Elevation 10.3 M.S.L.
HURRICANE SURVEY
STAMFORD, CONNECTICUT
FLOOD AREA AND DAMAGES
U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
BOSTON, MASS. APRIL 1958
SCALE AS SHOWN
PLATE D-1

PLATE D-1





	RANGE "A" 1□ = $16,000			RANGE "B" 1□ = $26,650			RANGE "C" 1□ = $80,000			TOTAL	
	AREA □"	ANNUAL LOSS	ANNUAL BENEFIT	AREA □"	ANNUAL LOSS	ANNUAL BENEFIT	AREA □"	ANNUAL LOSS	ANNUAL BENEFIT	ANNUAL LOSS	ANNUAL BENEFIT
NATURAL	8.81	$150,900	—	4.78	$136,300	—	1.06	$90,800	—	$378,000	—
MODIFIED	2.43	$41,000	$109,900	—	—	$136,300	—	—	$90,800	$41,000	$337,000



HURRICANE SURVEY

STAMFORD, CONNECTICUT

CURVES FOR ECONOMIC ANALYSIS

U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
BOSTON, MASS. MARCH, 1956

PLATE D-2

APPENDIX E

DESIGN AND COST ESTIMATES

APPENDIX E

DESIGN AND COST ESTIMATES

INTRODUCTION

E-1. This appendix presents details of design features and cost estimates for the selected plan of hurricane protection for Stamford, Connecticut, (Plan "E"). The principal features of the plan are shown on Plates E-1 through E-7.

SURVEYS AND EXPLORATIONS

E-2. The design and cost estimates for the selected plan are based on topographic and hydrographic surveys and subsurface explorations accomplished in 1956 and 1957. A total of 54 borings, 46 on land and 8 underwater, were made along considered alignments of various plans of protection. In addition, 21 probings were made with an iron pipe to ascertain the presence of rock and hard material in the areas of the East Branch where dredging will be required.

DESIGN CRITERIA

E-3. The structures have been designed to withstand a design hurricane producing a still-water elevation of 16.0 feet msl, accompanied by waves of 2 feet in the West Branch channel, 4 feet in the East Branch channel and 2 feet in the Westcott Cove-Cummings Park area. Top elevations varying from 16.0 to 18.0 feet msl were selected for the top of structures in order to provide protection against the design hurricane still-water and waves. In the case of a design wave breaking against a structure at the time of peak floodings, during the rare occurrence of a design hurricane, the top of runup for protective works on the east bank of the West Branch would be below the top of dikes and a maximum of three feet above the top of concrete walls. At the East Branch, the top of runup would be one foot above the top of the dikes and barrier and four feet above the top of the gate. In the Westcott Cove-Cummings Park area, the maximum runup in a design hurricane would be below the top of dikes. The infrequent overtopping would not appreciably reduce the effectiveness or safety of the project structures. For detailed discussion of the design hurricane and wave overtopping see Appendix B.

SELECTED PLAN OF PROTECTION (Plan "E")

E-4. DESCRIPTION OF PLAN

a. General. The selected plan of protection consists of a barrier with gated opening, about 1030 feet long, crossing the East Branch at Stamford, at a point, approximately 900 feet north

of Ware Island; and two closure dikes, one, 1060 feet long, extending easterly from the east end of the barrier, along the north side of Wallace Street to high ground near the intersection of Wallace Street and Shippan Avenue, and the other, 370 feet long, at the west end of the barrier, providing closure to high ground in Dyke Park, south of Woodland Cemetery. Supplemental closure dikes and walls are located along the east bank of the West Branch at Stamford and in the Westcott Cove-Cummings Park area, 3860 and 4400 feet long, respectively. See General Plan, Plate E-1. Included in the plan of improvement are the following structures:

(1) A gated navigation opening, 75 feet wide, in the East Branch barrier at its crossing of the existing channel.

(2) A 40,000 gpm pumping station located in the West Branch protection at the dike crossing of the small tidal inlet west of Dyke Park.

(3) Twelve stoplog structures with widths varying from 4 to 30 feet and heights varying from 6 to 11 feet. Five of these structures are at highway crossings.

The alignment and location of all structures are shown on Plates E-2 through E-5.

b. Barrier. The East Branch barrier will be of earth-fill, rock faced construction with a top elevation of 18.0 feet msl and a top width of 20 feet increasing to 30 feet at gate abutments. The top surface is treated and provided with guard rails to serve as an access road to the navigation gates. For details see Plates E-3 and E-6.

(1) The 75-foot navigation opening will be provided with sector gates which are closed during a hurricane. They will be contained in recesses in the abutments during normal periods. The gates consist of two similar leaves with a radius of 46.2 feet and an overall height of 36 feet. Details of the gates are shown on Plate E-6.

c. Dikes and Walls. The dikes along the east bank of the West Branch will be constructed of earth-fill with rock on the top and seaward slope and seeded topsoil on the landward slope. They will have a top elevation of 18.0 feet msl and a top width of 10 feet. The dike extensions to the East Branch barrier and the dikes in the Westcott Cove-Cummings Park area will be similar to those in the West Branch area, with top elevations varying from 16.0 to 18.0 feet msl. The concrete wall in the northern half of the West Branch protection is a T-wall type section. Also included in this same area are two short sections of sheet-steel pile bulkhead wall totaling 220 feet in length. See Plates E-2, E-3, E-4.

d. Pertinent Data. Pertinent data on Plan "E" structures are summarized in Table E-1, on following page.

TABLE E-1

PERTINENT DATA

HURRICANE PROTECTION PLAN "E"

Stamford, Connecticut

East Branch Protection

Barrier

Type: Earth-fill, rock toes and rock-faced slopes

Length (including gated opening)	1,030 feet
Top elevation	18.0 feet msl
Top width	20.0 feet
Average height	21.0 feet
Side slopes	1 on 2.5

Navigation Gates

Type: Sector

Width of navigation opening	75 feet
Number of gates	2
Interior angle of each gate	60°
Radius of each gate	46.2 feet
Outer circumference of each gate	48.4 feet
Top elevation	18 feet msl
Sill elevation	-18 feet msl
Height of each gate	36 feet

Dikes

Type: Earth-fill, rock on top and seaward slope and seeded topsoil on landward slope

Length	1,410 feet
Top elevation	16.0 - 18.0 feet msl
Top width	10 feet
Average height	11 feet
Side slope, seaward	1 on 1.5
Side slope, landward	1 on 2.0

TABLE E-1 (cont'd)

West Branch Protection

Dike

Type: Earth-fill, rock on top and seaward slope, seeded topsoil on landward slope

Length	1,810 feet
Top elevation	16.0 - 18.0 feet msl
Top width	10 feet
Average height, on land	10 feet
Average height, in water	20 feet
Side slope, seaward, on land	1 on 1.5
Side slope, seaward, in water	1 on 2.0
Side slope, landward	1 on 2.0

Walls

Type: Concrete T-Wall	
Length	1,780 feet
Top elevation	16.0 - 17.0 feet msl
Type: Sheet pile bulkhead	
Length	220 feet
Top elevation	17.0 feet msl

Pumping Station

Structure: Concrete	30 x 49 feet
Capacity	40,000 gpm
Sluice gates	
Number	2
Size	4 x 4 feet

Stoplog Structures

Number	9
Width of opening	4 to 30 feet
Height of opening	6 to 10 feet

Westcott Cove Protection

Dike

Type: Earth-fill, rock on top and seaward slope, seeded topsoil on landward slope

Length	4,400 feet
Top elevation	17.0 - 18.0 feet msl

TABLE E-1 (cont'd)

Westcott Cove Protection (cont'd)

Dike (cont'd)

Top width	10 feet
Average height	10 feet
Side slope, seaward	1 on 1.5
Side slope, landward	1 on 2.0

Stoplog Structures

Number	3
Width of opening	20 and 30 feet
Height of opening	10 and 11 feet

E-5. MODIFICATIONS TO SEWERAGE AND DRAINAGE FACILITIES

a. Modifications to sewer lines. The sewage treatment plant for the city of Stamford is located in an area afforded protection by the East Branch barrier and dike. Lines carrying sewerage to the treatment plant will be reinforced or replaced with new sections of pipe where they pass under the protective works. Valves will be installed in all such lines, where required, to prevent the entry of hurricane tidal flood waters. Also, manholes will be made watertight where necessary. Effluent from the treatment plant will be ponded in the pool formed behind the East Branch barrier when the gates are closed during a hurricane.

b. Modifications to drainage lines. Existing drainage pipes passing under the proposed structures will be replaced with cast iron pipe where necessary to carry the weight added by such structures. Each line will be provided with a tide gate chamber or a cast iron flap valve to prevent the entry of tidal waters. Among the lines to be so protected are a 24-inch drain along Rippowam Road and a 36-inch line crossing Cummings Park, south of McMullen Avenue. Along the landward side of dikes and walls, catch basins, paved ditches and under drains will be constructed to collect and conduct runoff to existing drainage facilities or to tide water.

At the cooling water intake of the Hartford Electric Light Company plant on the West Branch, provisions will be made for the raising of pump motors to prevent damage and allow for operation during a hurricane. In addition, three sluice gates will be installed at the outlets of the cooling water discharge lines to prevent the entry of tidal-flood waters.

A new interceptor line will be installed along South Street and Dyke Lane, south of Atlantic Street, to conduct interior runoff from the existing storm drainage system to the proposed pumping station during periods of coincident high tides and rainfall.

E-6. LANDS AND DAMAGES

The cost of furnishing necessary lands and rights-of-way, which will be one requirement of local cooperation, has been estimated upon the basis of a field reconnaissance and the application of current market values as determined from a study of a number of recent sales in the general area. The estimate includes allowances for resettlement costs, the payment of severance damages, and acquisition costs. The lands and improvements to be acquired, and the land upon which either temporary or permanent easements will be secured, are summarized below:

Land:

Acquired in fee, for structures	2.5 acres
Construction easements, temporary	4.0 acres
Permanent easements	10.5 acres
Total	17.0 acres

Improvements:

One summer home

E-7. RELOCATIONS

The construction of Plan "E" structures will not require the relocation of any highways, railroads, or water lines. A large portion of the parking area at West Beach, a public beach on the west shore of Westcott Cove, will be occupied by the dike. To maintain adequate parking facilities, it is proposed that a new parking area be developed on the north side of Rippowam Road, at its easterly end, or to relocate the bath houses in this location and extend the present parking area. A new entrance to the boat yard on the west side of the entrance to the lagoon at Cummings Park will be provided from an existing road in the park.

E-8. GEOLOGY OF SITE

The geology of the area and the foundation conditions for the protective structures in Plan "E" are discussed in Appendix A. The results of the subsurface explorations are shown on Plates A-1 through A-5.

E-9. AVAILABLE MATERIALS

Information on the availability of required construction materials in the Stamford area is contained in Appendix "A". A portion of the material taken from the excavation of the temporary bypass channel will be stockpiled for use in the construction of the barrier and dikes. Approximately 50 percent of the required fill will come from this source. The remainder of the required pervious fill will be dredged from Westcott Cove. A portion of this fill will be taken from within the limits of the existing navigation project for the cove, thereby providing some benefits in the nature of advance maintenance. The dredged material will be stockpiled to permit inspection and selection before placing in embankment.

E-10. PLAN OF CONSTRUCTION

The structures of Plan "E" will require about two years to construct and to put into operation. The construction schedule, predicated on the erection of the navigation gates and gate structures in the dry, by cofferdamming, and by the provision of a temporary by-pass channel for navigation during the construction period, will be generally as follows:

a. During the first year, the bypass channel in the East Branch will be dredged, the cofferdam constructed in the existing channel, and the inclosed area unwatered. Construction of the barrier section east of the navigation opening will be completed at least to an elevation of five feet above msl to provide access from the east bank of the Branch to the work area at the gate structure. The gate abutments, installation and testing of gates and equipment, and removal of the cofferdam will also be accomplished by the close of the first year.

b. Filling in of the temporary by-pass channel and completion of the barrier to design elevation will be accomplished in the second year.

c. Other features of the project such as land dikes, walls, pumping station, drainage modifications, and appurtenant structures, will be constructed concurrently with the barrier and the navigation gates.

BASIS OF ESTIMATES OF FIRST COST AND ANNUAL CHARGES

E-11. COST ESTIMATES

The cost of Plan "E" has been estimated on the basis of a design which will provide economical and secure structures. Estimates of quantities have been made on the basis of the typical cross sections and details shown on Plates E-2 through E-7. Earth borrow items include spoil, compaction in fill, and loss from borrow to fill.

E-12. UNIT PRICES

Unit prices are based on averages for similar types of projects either constructed, under construction, or under contract in New England and, where applicable, similar construction in other parts of the country. Adjustments have been made for the availability and locations of material required. The adopted unit prices, which are on a 1957 price level, also reflect adjustments to include minor items of work such as the installation of signal lights on the gate structure and other aids to navigation which do not appear as separate items in the cost estimates.

E-13. CONTINGENCIES, ENGINEERING AND OVERHEAD

The estimate includes a 20 percent allowance to cover contingencies. The cost of engineering, design, supervision, and administration are estimated lump sums based on knowledge of the site and experience. These items of cost, for various phases of the plan, are shown in Table E-2 on the following pages.

E-14. LOCAL CONTRIBUTIONS

It is proposed that local interests contribute in cash towards the first cost of the project an amount presently estimated at $2,286,000. (See Table E-3). This amount has been derived as follows:

a. An amount of $1,406,000 which represents 30% of the first cost of the project less credit for furnishing lands, easements, and rights-of-way and accomplishing necessary modifications to sewerage and drainage facilities.

b. An amount of $880,000 which equals the capitalized value of an annual operation and maintenance cost of $31,000 over a 50-year period. This contribution would be made in lieu of operation and maintenance of the East Branch barrier, dikes, and gate by local interests.

E-15. ANNUAL CHARGES

The estimate for annual charges is based on 2.5 percent interest on the total investment and amortization of the investment over a period of 50 years. The total investment, Federal plus non-Federal, equals the first costs plus 2.5 percent interest for one year or one-half of the estimated construction period of two years. No allowance for the loss of taxes on lands is included in the annual charges since a large percentage of the lands are publicly owned. The loss of taxes from the acquisition of land now privately owned would be small. Costs of maintenance and operation of the project are based on a knowledge of the site and costs of similar projects.

FIRST COSTS AND ANNUAL CHARGES

E-16. FIRST COSTS

The first cost of Plan "E" is estimated at $5,586,000 of which $3,030,000 would be borne by the United States and local interests would contribute in cash $2,286,000 and provide lands, easements, and rights-of-way, and accomplish all necessary modifications to sewer and drainage facilities and necessary relocations

at an estimated cost of $270,000, a total local first cost of $2,556,000. The costs of the individual structures are shown in detail in the following table, Table E-2. Detailed breakdowns of the estimates, by principal features of the work, and by quantities and unit prices, are also shown in Table E-2.

E-17. ANNUAL CHARGES

The total annual charges for Plan "E" amount to an estimated $248,000. Of this amount $144,000 represents Federal annual charges and $104,000, non-Federal. The determination of annual charges is shown in Table E-4.

TABLE E-2

ESTIMATED FIRST COSTS
(1957 Price Level)

HURRICANE PROTECTION PLAN "E"

Stamford, Connecticut

Item	Estimated Quantity	Unit	Unit Price	Estimated Amount
East Branch Protection				
Preparation of site	8	acre	L.S.	$ 2,000
Earth excavation, channel	100,000	c.y.	2.00	200,000
Earth excavation, common	10,000	c.y.	1.50	15,000
Earth excavation, stockpile	60,000	c.y.	.70	42,000
Earth fill	50,000	c.y.	.30	15,000
Crushed stone	2,500	c.y.	8.00	20,000
Rock fill, 20#	5,500	c.y.	8.00	44,000
Rock fill, 100#	4,000	c.y.	10.00	40,000
Rock fill, 400#	11,000	c.y.	10.00	110,000
Rock fill, quarry-run	35,000	c.y.	8.00	280,000
Gravel	1,500	c.y.	4.00	6,000
Topsoil, seeded	1,000	c.y.	5.00	5,000
Navigation gates				
Cofferdam and unwatering	1	job	L.S.	400,000
Earth excavation	20,000	c.y.	2.00	40,000
Rock excavation	2,000	c.y.	10.00	20,000
Grouting & dowelling	1	job	L.S.	30,000
Concrete, reinforced				
below elev. -18.0 msl	4,500	c.y.	60.00	270,000
above elev. -18.0 msl	4,500	c.y.	70.00	315,000
Gates & equipment	1	job	L.S.	445,000
Pavement	5,000	s.y.	3.00	15,000
Guard Rail	3,000	L.F.	5.00	15,000
Drainage facilities	1	job	L.S.	10,000
Miscellaneous	1	job	L.S.	15,000
Sub-total				$ 2,354,000
Contingencies				471,000
				$2,825,000
Engineering and design				256,000
				$3,081,000
Supervision and administration				245,000
Total Cost - East Branch Protection				$3,326,000

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TABLE E-2 (cont'd)

Item	Estimated Quantity	Unit	Unit Price	Estimated Amount
West Branch Protection				
Preparation of site	6.0	acre	L.S.	$ 3,000
Earth excavation, common				
Dikes	4,000	c.y.	1.50	6,000
Walls	12,000	c.y.	2.00	24,000
Earth excavation, borrow from Westcott Cove	20,000	c.y.	1.50	30,000
Earth excavation, stockpile from Westcott Cove	15,000	c.y.	.80	12,000
Earth excavation, stockpile from channel, E. Branch	10,000	c.y.	.70	7,000
Earth fill	10,000	c.y.	0.30	3,000
Back fill (walls)	8,000	c.y.	1.00	8,000
Crushed stone	1,500	c.y.	8.00	12,000
Rock fill 5#	2,500	c.y.	6.00	15,000
Rock fill 50#	6,500	c.y.	8.00	52,000
Rock fill, quarry run	4,000	c.y.	8.00	32,000
Gravel	1,000	c.y.	4.00	4,000
Topsoil, seeded	400	c.y.	5.00	2,000
Walls				
Concrete, reinforced	600	c.y.	80.00	48,000
Concrete, reinforced	2,900	c.y.	100.00	290,000
Sheet steel piling	200	ton	400.00	80,000
Stoplog structures				
30' wide x 10' high	1	ea.	15,000	15,000
30' " x 6' "	2	ea.	7,000	14,000
15' " x 9' "	4	ea.	4,000	16,000
10' " x 9' "	1	ea.	3,000	3,000
4' " x 9' "	1	ea.	1,000	1,000
Pumping station	1	job	L.S.	260,000
Drainage facilities	1	job	L.S.	30,000
Modification of intake and discharge, Hartford Elec.Lt.Co.	1	job	L.S.	30,000
Pavement	1,000	s.y.	3.00	3,000
Guard Rail	600	L.F.	5.00	3,000
Miscellaneous		L.S.		10,000
Sub-total				$1,013,000
Contingencies				202,000
				$1,215,000
Engineering and design				109,000
				$1,324,000
Supervision and administration				106,000
Total Cost - West Branch Protection				$1,430,000

TABLE E-2 (con't)

Item	Estimated Quantity	Unit	Unit Prices	Estimated Amount
Westcott Cove Protection				
Preparation of site	9	acres	L.S.	$ 3,000
Earth excavation, common	20,000	c.y.	1.50	30,000
Earth excavation, borrow (from Westcott Cove)	40,000	c.y.	1.50	60,000
Earth excavation, stockpile	30,000	c.y.	.70	21,000
Earth fill	30,000	c.y.	.30	9,000
Rock fill, 5#	4,500	c.y.	6.00	27,000
Rock fill 50#	17,000	c.y.	8.00	136,000
Gravel	2,000	c.y.	4.00	8,000
Topsoil seeded	1,200	c.y.	5.00	6,000
Miscellaneous	1	job	L.S.	15,000
Stoplog structures				
20' wide x 11' high	1	ea.	10,000	10,000
30' " x 10' "	2	ea.	15,000	30,000
Drainage facilities	1	job	L.S.	40,000
Sub-total				$ 395,000
Contingencies				79,000
				$ 474,000
Engineering and design				43,000
				$ 517,000
Supervision and administration				43,000
Total Cost - Westcott Cove Protection				$ 560,000
Modification to Drainage and Sewerage Facilities				
New drainage interceptor at South St. and Dyke Lane	1	job	L.S.	$ 75,000
Sanitary sewer facilities	1	job	L.S.	10,000
				$ 85,000
Contingencies				17,000
				$ 102,000
Engineering and design				9,000
				$ 111,000
Supervision and administration				9,000
Total Cost - Modification to Drainage and Sewerage Facilities				$ 120,000

TABLE E-2 (cont'd)

Item	Estimated Quantity	Unit	Unit Price	Estimated Amount
Lands and Damages				
Land (in fee)	2.5	acres	L.S.	$ 45,000
Permanent easements	10.5	acres	L.S.	65,000
Temporary easements	4.0	acres	L.S.	5,000
Permanent access	1	job	L.S.	1,000
Improvements acquired				7,000
Severance damage	1	job	L.S.	1,000
Sub-total				$ 124,000
Contingencies				18,000
				142,000
Resettlement cost				1,000
Acquisition costs				7,000
Total Cost - Lands and Damages				$150,000

Summary

East Branch Protection	$3,326,000
West Branch Protection	1,430,000
Westcott Cove Protection	560,000
Modification to Storm Drainage and Sanitary Sewerage Facilities	120,000
Lands and Damages	150,000
Sub-total - First Cost	$5,586,000
Aids to Navigation (U.S. Coast Guard)	14,000
Preauthorization Studies	50,000
Total - Project Cost	$5,650,000

TABLE E-3

COST ALLOCATION

HURRICANE PROTECTION PLAN "E"

Stamford, Connecticut

Item	Federal	Local	Total
First Cost	$3,910,000	$1,676,000(2)	$5,586,000(1)
Capitalized value of annual cost for operation and maintenance of East Branch barrier and gate	-880,000(3)	880,000(3)	
	$3,030,000	2,556,000	$5,586,000
Aids to navigation	14,000		14,000
Preauthorization studies	50,000		50,000
Project Cost	$3,094,000	$2,556,000	$5,650,000
Modification to sewerage and drainage facilities		-150,000	
Acquisition of lands, easements and rights-of-way		-120,000	
Local Cash Contribution	(Total)	$2,286,000	

(1) From Summary, Table E-2.

(2) Thirty percent of first cost.

(3) Present worth of future annual cost to the United States of $31,000.

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TABLE E-4

ESTIMATED ANNUAL CHARGES
(1957 Price Level)

HURRICANE PROTECTION PLAN "E"

Stamford, Connecticut

Federal Investment

First cost	$ 3,030,000
Aids to navigation	14,000
Preauthorization studies	50,000
	$ 3,094,000
Interest during construction	77,000
Total Federal Investment	$ 3,171,000

Federal Annual Charges

Interest on investment, 2.5%		79,000
Amortization, 1.026%		33,000
Major replacements		2,000
Maintenance and operation		
East Branch Barrier & Gate		
Salaries	16,000	
Transportation & supplies	2,000	
Embankment and general	2,000	
Concrete features	3,000	
Gates and accessories	6,000	
		29,000
Aids to navigation (1)		1,000
Total Federal Annual Charges		$ 144,000

Non-Federal Investment

Contributed funds	$2,286,000
Modifications to sewer and drainage facilities	120,000
Lands, easements & rights-of-way	150,000
	$2,556,000
Interest during construction	64,000
Total Non-Federal Investment	$2,620,000

(1) U.S. Coast Guard

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TABLE E-4 (cont'd)

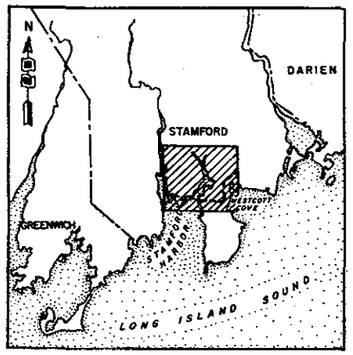
Non-Federal Annual Charges

Interest on investment, 2.5%		$ 66,000
Amortization, 1.026%		27,000
Major replacements		1,000
Maintenance and operations		
Salaries	2,500	
Transportation and supplies	500	
Embankment and general	2,000	
Concrete features	2,000	
Pumping station	3,000	10,000
Total Non-Federal Annual Charges		$104,000
TOTAL ANNUAL CHARGES		248,000
TOTAL ANNUAL BENEFITS (From Appendix D)		363,000
RATIO OF ANNUAL BENEFITS TO ANNUAL CHARGES		1.5 to 1.0

R. 2-9-59

CORPS OF ENGINEERS

U.S. ARMY



LOCATION MAP

SCALE IN MILES

½ 0

N

LIMIT OF FLOODING
DESIGN HURRICANE
EL. 16.0 M.S.L.

STAMFORD

WEST BRANCH

EAST BRANCH

STAMFORD HARBOR

JEFFERSON ST.

CANAL ST.

LUDLOW ST.

HIGH ST.

SEWAGE TREATMENT PLANT

MILL RIVER

SHIPPAN AVE.

LIMIT OF FLOODING
DESIGN HURRICANE
EL. 16.0 M.S.L.

SANDBAG

SANDBAG

SOUNDVIEW AVE.

WEEDEN AVE.

AVE.

CUMMINGS PARK

STOP LOG

HARTFORD ELECTRIC LIGHT CO.

DYKE LANE INTERCEPTOR

SO. PACIFIC ST.

CONCRETE WALL

WOODLAND CEMETERY

DYKE LANE

ELMCROFT ST.

ACCESS ROAD

STOP LOG

WEST BRANCH DIKE

STOP LOG

PUMPING STATION

ACCESS ROAD

STOP LOG

DYKE PARK

HARBOR BARRIER & DIKE

75' GATED OPENING

ACCESS ROAD

MAINTENANCE AREA

LINCOLN ROAD

WESTCOTT COVE DIKE

SHIPPAN AVE.

KIPPEWAM ROAD

INDIANOLA ROAD

STOP LOG

STOP LOG

WALLACE ST.

MITCHELL ST.

LIMIT OF FLOODING
DESIGN HURRICANE
EL. 16.0 M.S.L.

EAST BEACH

WESTCOTT COVE

WEST BEACH

PLAN

SCALE IN FEET

200 0 200 400 600

U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
BOSTON, MASS.

DR. BY	TR. BY	CK. BY
R.J.M.	R.J.M.	J.L.I.

PROJECT ENGINEER

CHIEF, HURRICANE UNIT NO. 2

SUPERVISED BY:

CHIEF, PLANS & SPECS. BRANCH

APPROVED

CHIEF, ENGINEERING DIV.

APPROVED

LT. COL. C.E. ASST. TO DIVISION ENGINEER

HURRICANE SURVEY
STAMFORD, CONN.
PROTECTION PLAN "E"
GENERAL PLAN

DATE APRIL 1958

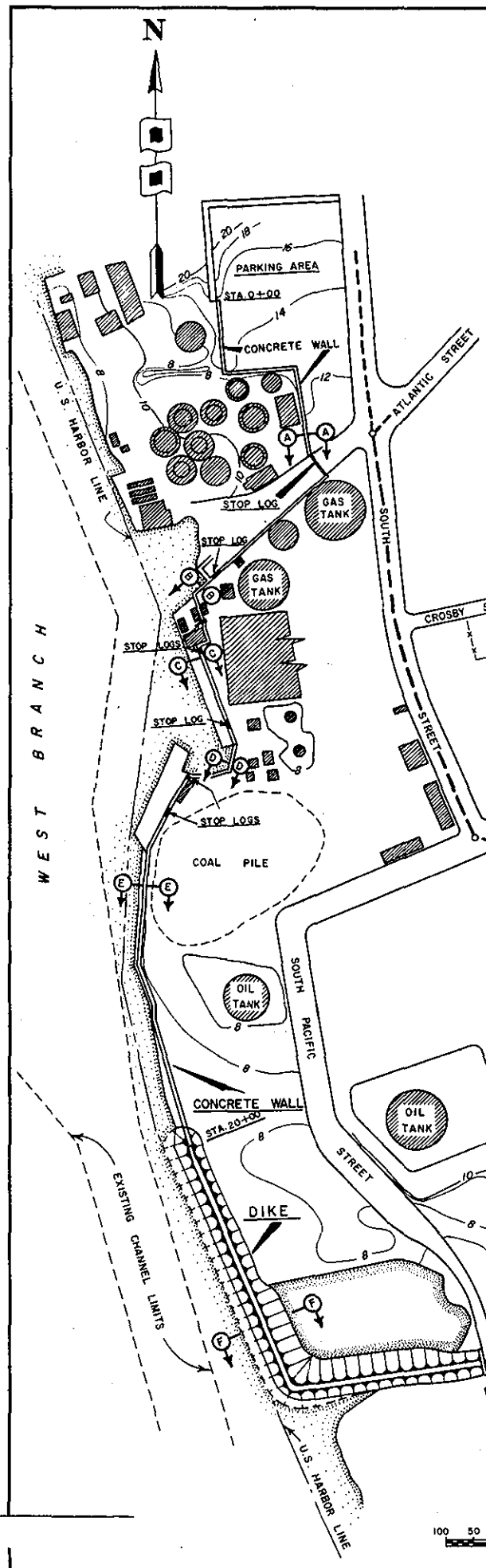
TO ACCOMPANY REPORT
DATED 8 APRIL 1958

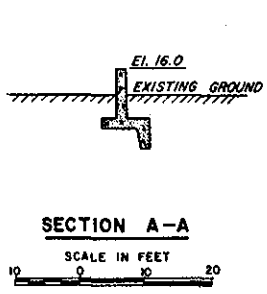
SCALE 1" = 200'

DRAWING NUMBER
ST-1-1002

SHEET 1 OF 7

PLATE E-1

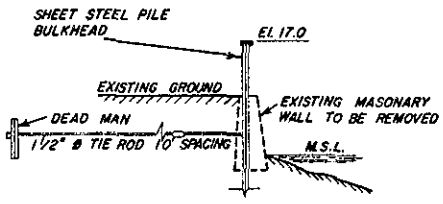




SECTION A–A

SCALE IN FEET

10 0 10 20



SECTION B–B

SCALE IN FEET

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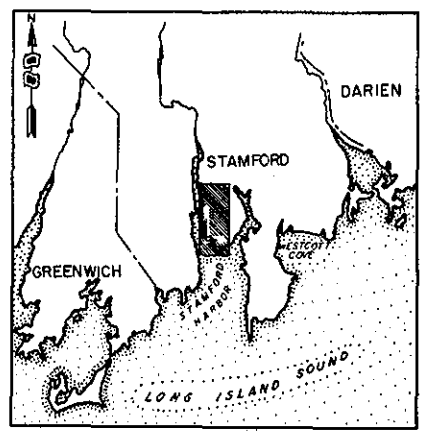
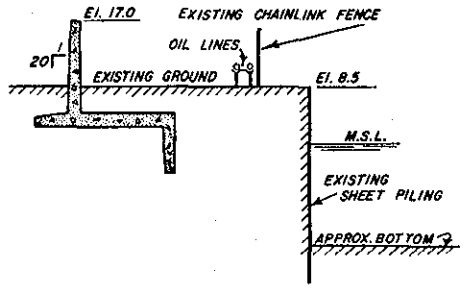


LOCATION MAP

SCALE IN MILES

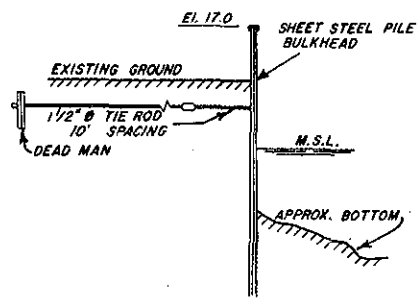
1/2 0



SECTION C–C

SCALE IN FEET

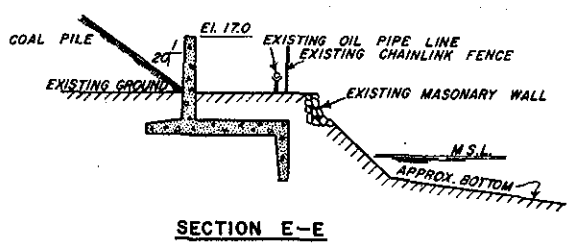
10 0 10 20



SECTION D–D

SCALE IN FEET

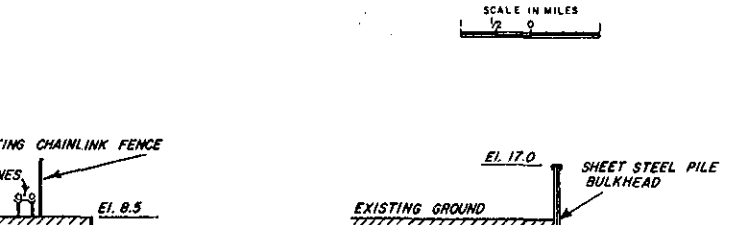
10 0 10 20



SECTION E–E

SCALE IN FEET

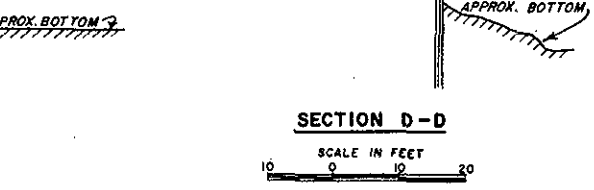
10 0 10 20



SECTION F–F

SCALE IN FEET

10 0 10 20



SECTION G–G

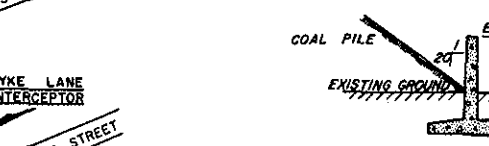
SCALE IN FEET

10 0 10 20

SECTION H–H

SCALE IN FEET

10 0 10 20



SECTION I–I

SCALE IN FEET

10 0 10 20

NOTE:

Elevations are in feet and are referred to Mean Sea Level Datum.

U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
BOSTON, MASS.

DR. BY R.J.M.	TR. BY R.J.M.	CK. BY J.L.I.

PROJECT ENGINEER

CHIEF, HURRICANE UNIT NO. 2

SUBMITTED BY
CHIEF PLANS & SURVEYS BRANCH

APPROVED
CHIEF ENGINEERING DIV.

APPROVED
LT. COL. C.E. ASST. TO DIVISION ENGINEER

HURRICANE SURVEY
STAMFORD CONN.
WEST BRANCH DIKE
PLAN AND SECTIONS

DATE APRIL 1958

TO ACCOMPANY REPORT
DATED 8 APRIL 1958

SCALE: AS SHOWN

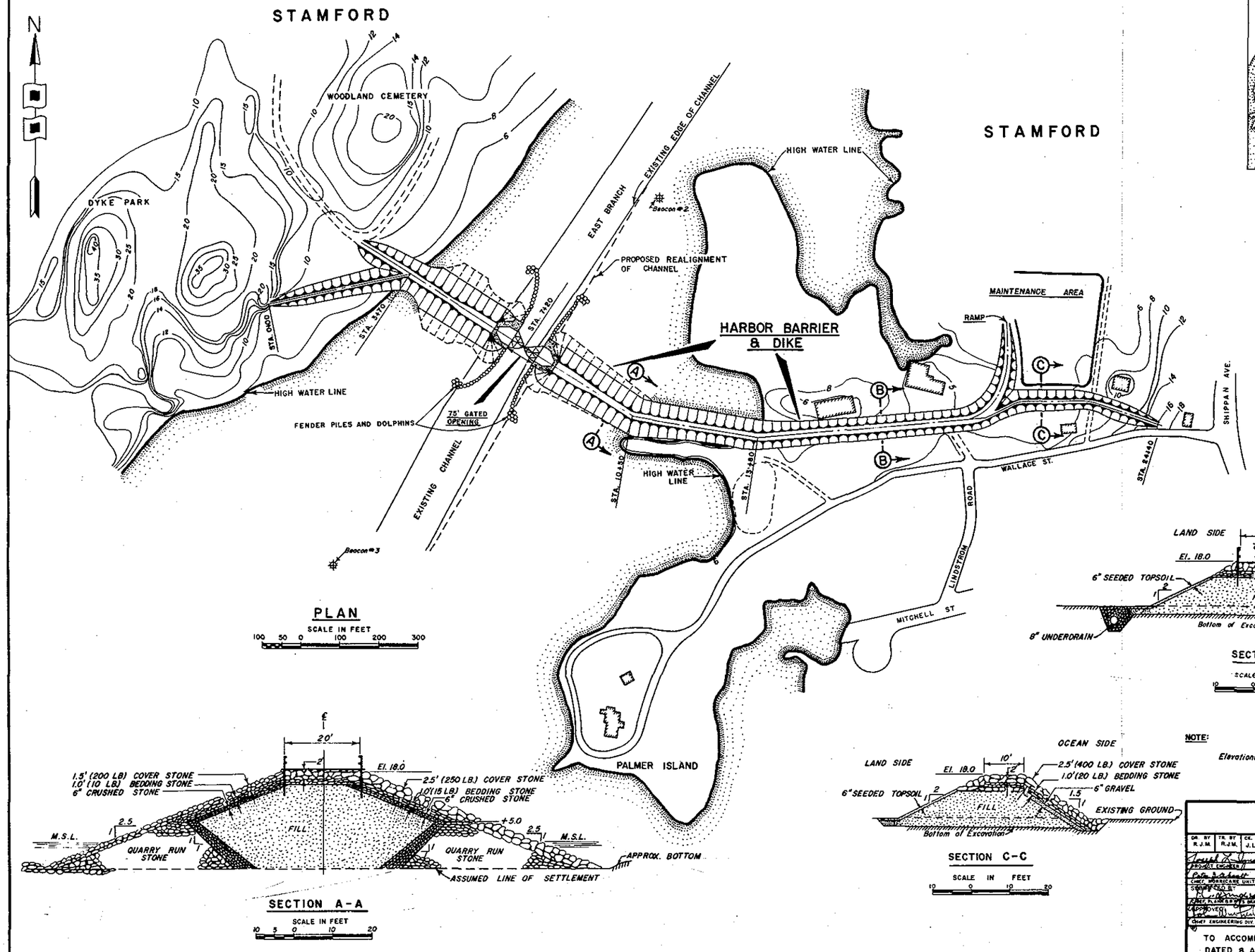
DRAWING NUMBER
ST-1-1003

SHEET 2 OF 7

PLATE E-2

PLATE E-2

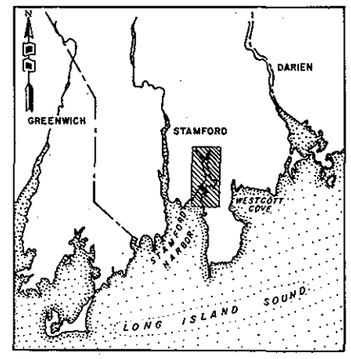
CORPS OF ENGINEERS — U. S. ARMY



PLAN

SCALE IN FEET

100 50 0 100 200 300



LOCATION MAP

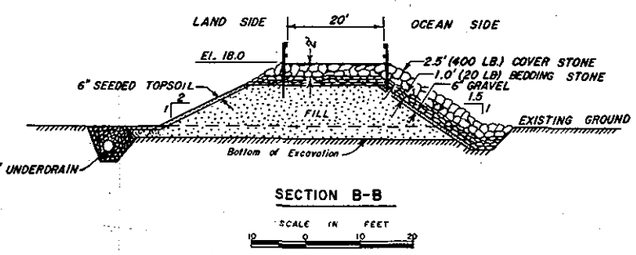
SCALE IN MILES

½ 0

SECTION A-A

SCALE IN FEET

10 5 0 10 20



SECTION B-B

SCALE IN FEET

10 0 10 20

SECTION C-C

SCALE IN FEET

10 0 10 20

NOTE:

Elevations are in feet and referred to Mean Sea Level Datum.

U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
BOSTON, MASS.

DR. BY R.J.M.	TR. BY R.J.M.	CK. BY J.L.L.

HURRICANE SURVEY
STAMFORD CONN.
EAST BRANCH
BARRIER & DIKE
PLAN AND SECTIONS

PROJECT ENGINEER
CHIEF HURRICANE UNIT
CHIEF, PLANS & SPEC. BRANCH
CHIEF ENGINEERING DIV.

APPROVED
LT.COL., C.E. ASST. TO DIVISION ENGINEER

DATE APRIL 1958

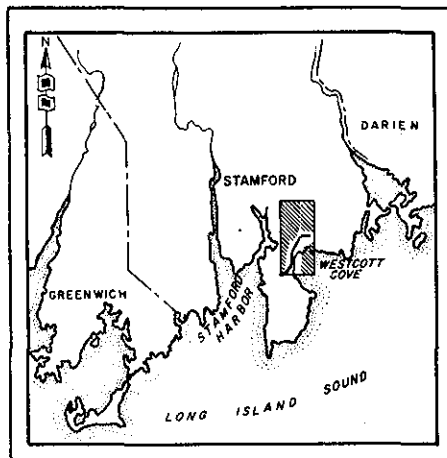
TO ACCOMPANY REPORT
DATED 8 APRIL 1958

SCALE AS SHOWN

DRAWING NUMBER
ST-1-1004

SHEET 3 OF 7

PLATE E-3



LOCATION MAP

SCALE IN MILES

½ 0

N

CUMMINGS PARK

STAMFORD

EAST AVE.

SANDBAG

SANDBAG

VANBUSKIRK AVE.

SOUNDVIEW AVE.

STA 44+00

McMULLEN AVE.

SHALLOW POND

DIKE

TENNIS COURT

EXISTING BASKETBALL COURT

STOP LOG

SEAVIEW AVE.

CUMMINGS PARK RD.

WHITE ST.

ACCESS ROAD

WESTCOTT COVE

DIKE

RIPPOWAM ROAD

STOP LOG

WAMPANAW RD.

WEST BEACH

IROQUOIS ROAD

DIKE

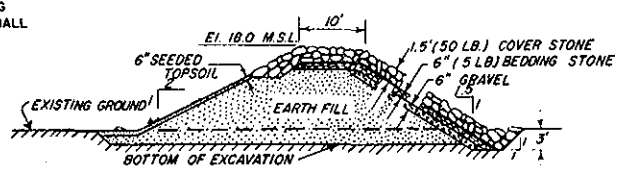
STOP LOG

STA 0+00

PLAN

SCALE IN FEET

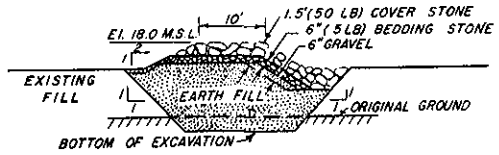
100 50 0 100 200 300



SECTION C-C

SCALE IN FEET

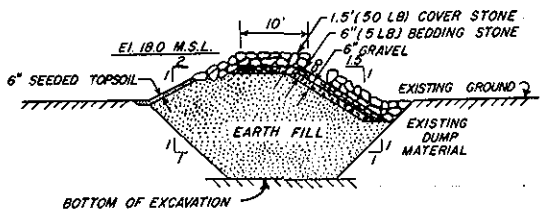
10 5 0 10 20



SECTION B-B

SCALE IN FEET

10 5 0 10 20



SECTION A-A

SCALE IN FEET

10 5 0 10 20

NOTE:

Elevations are in feet and are referred to Mean Sea Level Datum.

U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
BOSTON, MASS.

DR. BY	TR. BY	CK. BY
R.J.M.	R.J.M.	J.L.I.

PROJECT ENGINEER

CHIEF, HURRICANE UNIT NO. 2

SUPERVISED BY

CHIEF, PLANNING BRANCH

APPROVED

CHIEF ENGINEERING DIVISION

HURRICANE SURVEY
STAMFORD CONN.
WESTCOTT COVE DIKE
PLAN AND SECTIONS

APPROVED

LT. COL. C.E. ASST. TO DIVISION ENGINEER

DATE APRIL 1958

SCALE: 1" = 100'

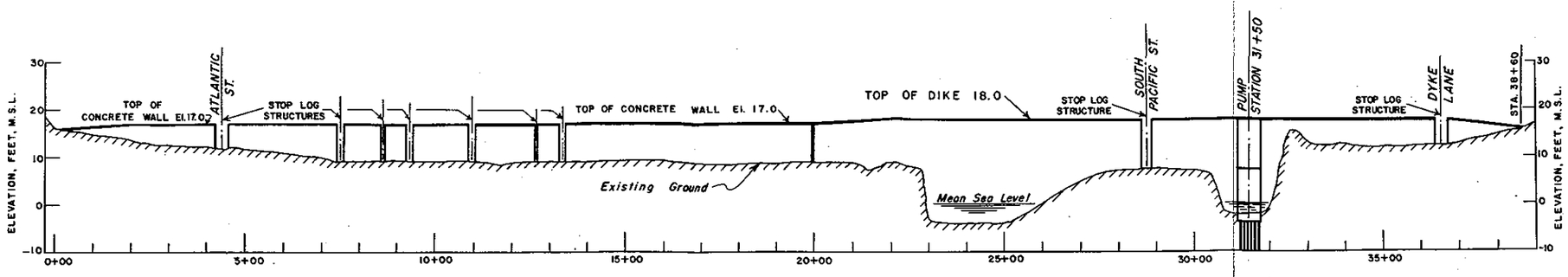
TO ACCOMPANY REPORT
DATED 8 APRIL 1958

DRAWING NUMBER
ST-1-1005

SHEET 4 OF 7

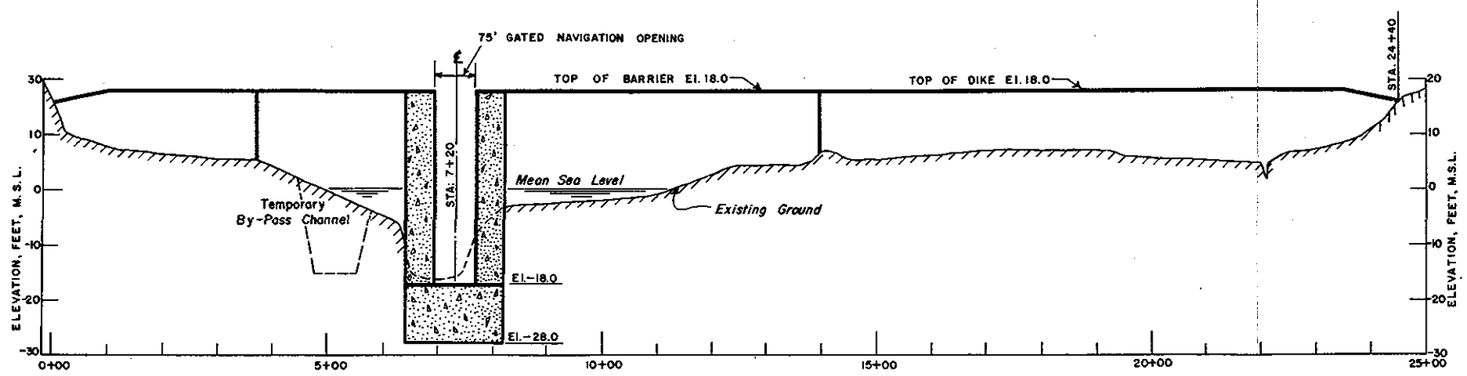
PLATE E-4

PLATE E-4



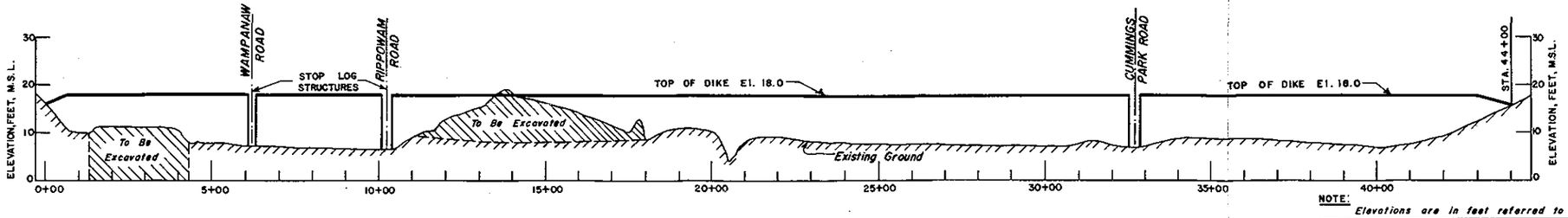
PROFILE ALONG ℄ WEST BRANCH DIKE

SCALE: AS SHOWN



PROFILE ALONG ℄ EAST BRANCH BARRIER AND DIKE

SCALE: AS SHOWN



PROFILE ALONG ℄ WESCOTT COVE DIKE

SCALE: AS SHOWN

NOTE: *Elevations are in feet referred to Mean Sea Level Datum.*

U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
BOSTON, MASS.

DR. BY	TR. BY	CK. BY
H.R.	H.R.	J.L.I.

PROJECT ENGINEER
CHIEF, HURRICANE UNIT NO 2
SUBMITTED BY
CHIEF, PLANS & SURVEYS BRANCH
APPROVED
CHIEF ENGINEERING DIV.

HURRICANE SURVEY
STAMFORD, CONN.
BARRIER & DIKES
PROFILES

APPROVED
LT.COL., C.E. ASST. TO DIVISION ENGINEER

DATE APRIL 1958

TO ACCOMPANY REPORT
DATED 8 APRIL 1958

SCALE: AS SHOWN

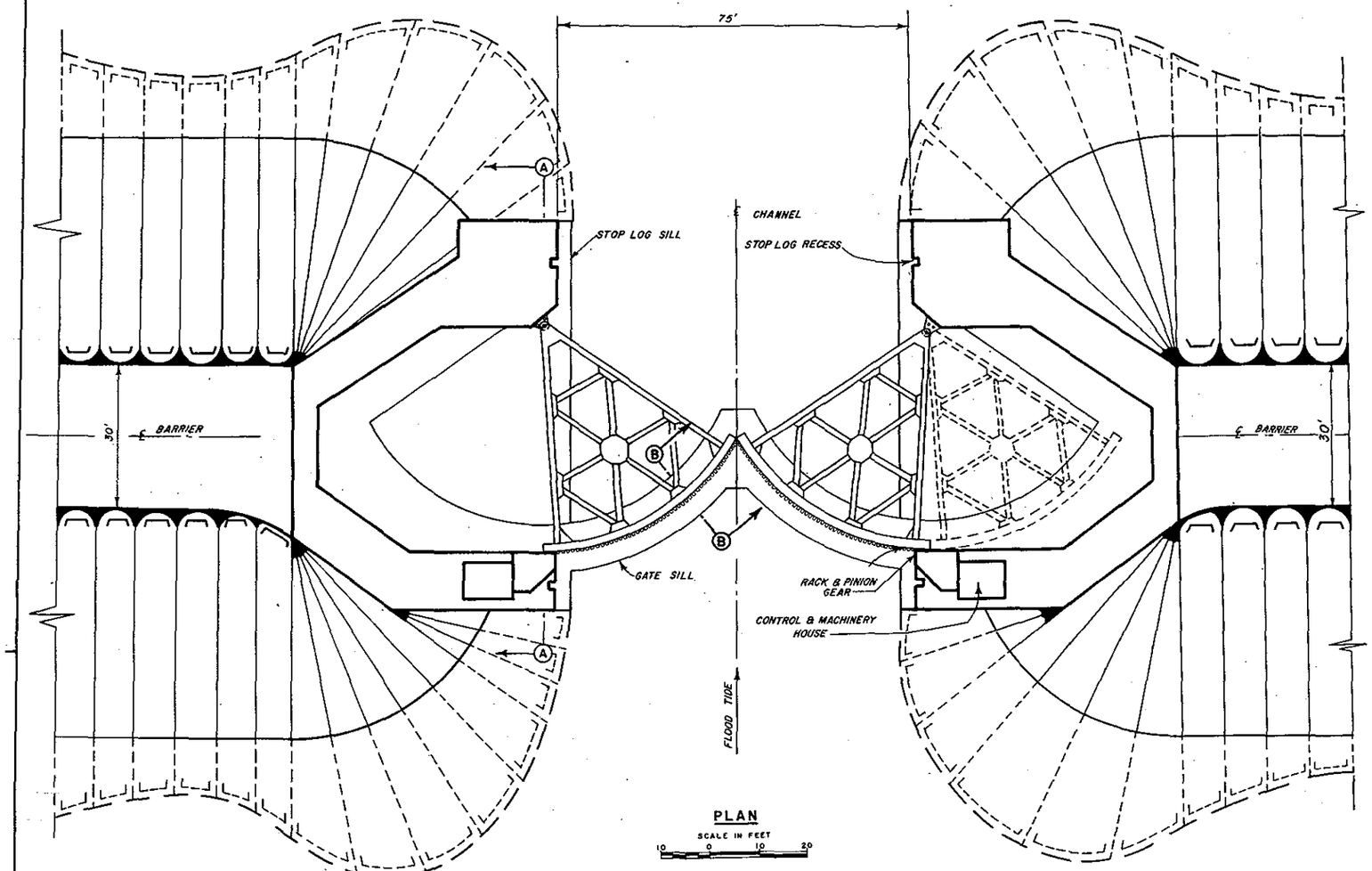
DRAWING NUMBER
ST-1-1006

SHEET 5 OF 7

PLATE E-5

CORPS OF ENGINEERS

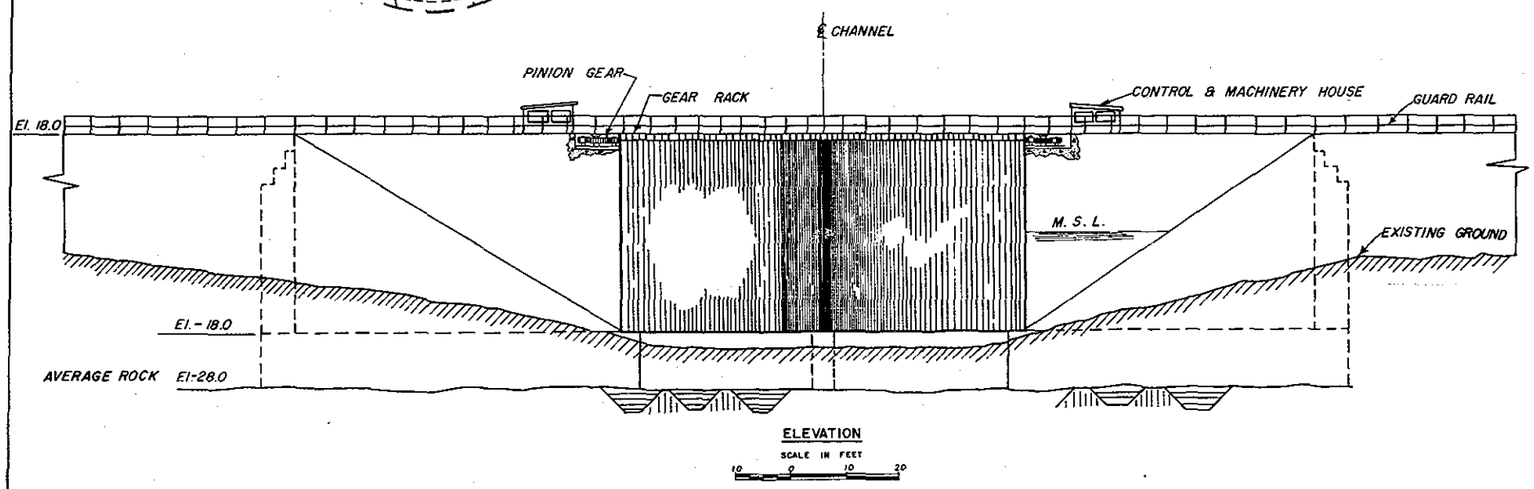
U.S. ARMY



PLAN

SCALE IN FEET

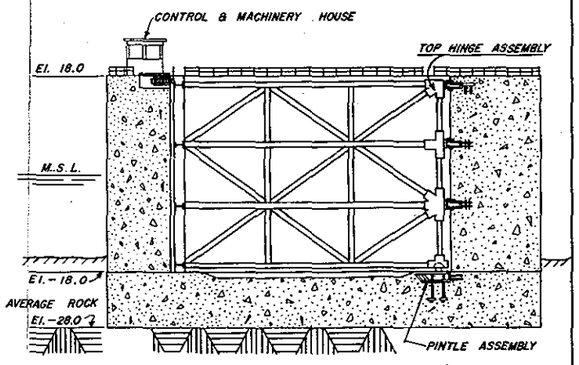
10 0 10 20



ELEVATION

SCALE IN FEET

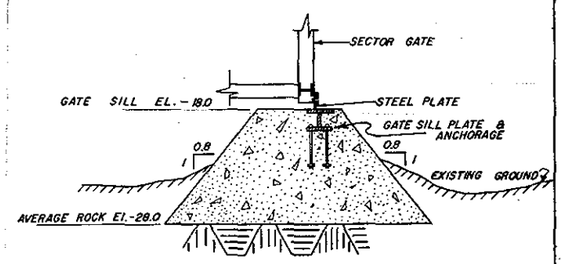
10 0 10 20



SECTION A-A

SCALE IN FEET

10 5 0 10 20



SECTION B-B

SCALE IN FEET

5 0 5 10

NOTE:

Elevations are in feet and are referred to Mean Sea Level Datum.

U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
BOSTON, MASS

DR. BY	TR. BY	CK. BY
H.G.	R.J.M.	J.L.S.

PROJECT ENGINEER

CHIEF, HURRICANE UNIT NE

SUPERVISED BY

CHIEF, PLANS & SURVEYS BRANCH

APPROVED

CHIEF ENGINEERING DIV.

HURRICANE SURVEY
STAMFORD CONN.
EAST BRANCH
HARBOR BARRIER & DIKE
SECTOR GATE

APPROVED

LT. COL. C.E. ASST. TO DIVISION ENGINEER

DATE APRIL 1958

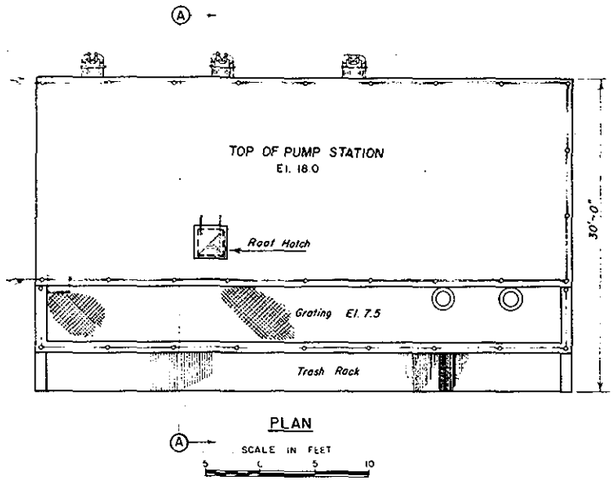
TO ACCOMPANY REPORT
DATED 8 APRIL 1958

SCALE AS SHOWN

DRAWING NUMBER
ST-1-1007

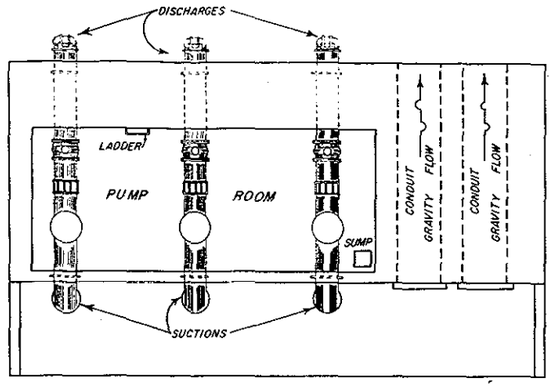
SHEET 6 OF 7

PLATE E-6



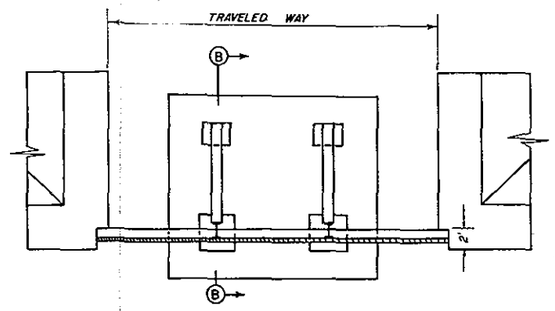
PLAN

SCALE IN FEET
5 0 5 10



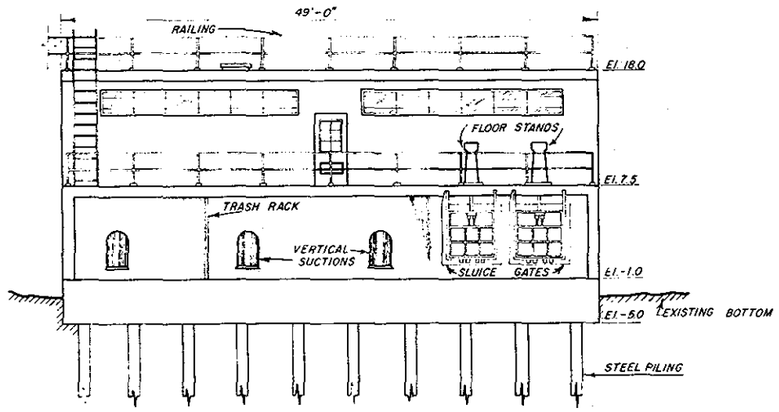
PLAN THROUGH PUMP ROOM

SCALE IN FEET
5 0 5 10



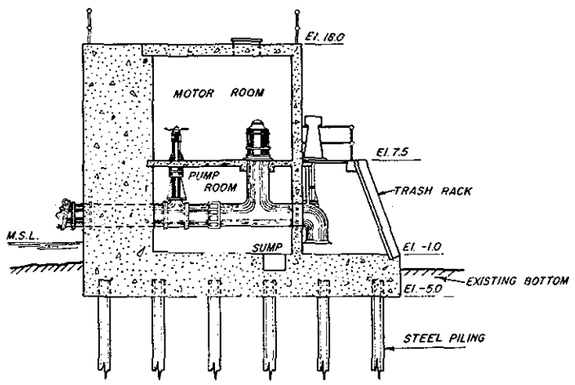
PLAN OF STOP LOG

SCALE IN FEET
5 0 5 10 15



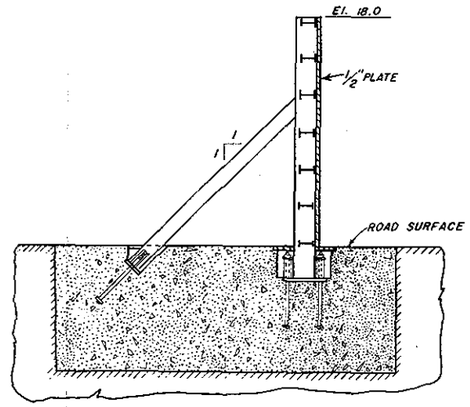
ELEVATION

SCALE IN FEET
5 0 5 10



SECTION A-A

SCALE IN FEET
0 5 10



SECTION B-B

SCALE IN FEET
0 1 2 3 4 5

NOTE
ELEVATIONS ARE IN FEET AND ARE REFERRED TO MEAN SEA LEVEL DATUM.

U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
BOSTON, MASS

DR. BY	TR BY	CK BY
H G	R J M	J L I

PROJECT ENGINEER
CHIEF, HYDRAULICS UNIT
SUBMITTED BY
CHIEF, PLANNING & DATA BRANCH
APPROVED
CHIEF ENGINEERING DIV

HURRICANE SURVEY
STAMFORD CONN.
WEST BRANCH DIKE
PUMP STATION AND STOPLOG DETAILS

APPROVED
LT COL, CE ASST TO DIVISION ENGINEER
DATE APRIL 1958

TO ACCOMPANY REPORT
DATED 8 APRIL 1958

SCALE AS SHOWN
DRAWING NUMBER
ST-1-1008
SHEET 7 OF 7

PLATE E-7

APPENDIX F

LETTERS OF COMMENT

DEPARTMENT OF
HEALTH, EDUCATION, AND WELFARE
REGIONAL OFFICE

PUBLIC HEALTH SERVICE

Region II
42 Broadway
New York 4, N.Y.

March 14, 1958

Refer to: 24:SE
Reference to: NEDGW

Lt. Col. Miles L. Wachendorf
Corps of Engineers, U. S. Army
Asst. Division Engineer for Civil Works
New England Division
150 Causeway Street
Boston 14, Massachusetts

Dear Colonel Wachendorf:

Reference is made to your letter of February 25, 1958 concerning the hurricane protection Plan "E" at Stamford, Connecticut.

We have reviewed the copy of the letter you received from Mr. Wise and concur in his comments.

We have no other comments to make at this time on the water supply, pollution control or vector control aspects of this project.

For the Regional Engineer.

Sincerely yours,

L. M. Klashman

Lester M. Klashman
Acting Assistant Regional Engineer
Water Supply and Water Pollution Control

STATE OF CONNECTICUT
WATER RESOURCES COMMISSION
STATE OFFICE BUILDING · HARTFORD 15, CONNECTICUT

March 4, 1958

Lt. Colonel Miles L. Wachendorf
Corps of Engineers, U. S. Army
New England Division
150 Causeway Street
Boston 14, Massachusetts

Dear Colonel Wachendorf:

This will refer to your letter of 27 February 1958 requesting the comments from this office concerning the hurricane protection project for the City of Stamford, Connecticut as proposed under Plan E. This Plan includes a barrier across the East Branch of Stamford Harbor with a gated structure.

The sanitary wastes from the City of Stamford are collected and treated in a modern sewage treatment plant. While there are storm water overflows and minor sources of pollution from both the sanitary sewer system and industrial plants, the total pollution from these sources is not great and probably not in sufficient quantity to materially affect the normal uses of the water.

It is our understanding that the presently proposed structure will have no appreciable effect upon any changes in the tidal regimen of the harbor at this point. Therefore, there would appear to be no objection to the proposed Plan E from the standpoint of the sanitary conditions of the harbor.

Very truly yours,

William S. Wise

William S. Wise
Director

WSW/jb

REGION 5

NEW ENGLAND STATES
NEW YORK
PENNSYLVANIA
NEW JERSEY
DELAWARE
WEST VIRGINIA

UNITED STATES
DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE
BUREAU OF SPORT FISHERIES AND WILDLIFE
OFFICE OF REGIONAL DIRECTOR
BLAKE BUILDING
BOSTON 11, MASSACHUSETTS

IN REPLY REFER TO:

September 16, 1957

The Division Engineer
N. E. Division
U.S. Corps of Engineers
150 Causeway Street
Boston 14, Mass.

Dear Sir:

Reference is made to your letter of July 1, 1957 relative to protection against tidal flooding at Stamford, Connecticut.

Our reply has been delayed because of the need to look into the matter and because this office expected to meet with your Mr. McAleer on this and related matters.

After considering the plan for relief from flooding, this office has concluded that the effects on fish and wildlife will be of a minor nature.

Very truly yours,

D R Gascoyne

D. R. Gascoyne
Regional Director

STATE OF CONNECTICUT
BOARD OF FISHERIES AND GAME
2 WETHERSFIELD AVENUE · HARTFORD, CONNECTICUT

ADDRESS ALL MAIL TO
STATE OFFICE BUILDING, HARTFORD

July 22, 1957

Miles L. Wachendorf
Lt. Colonel, Corps of Engineers
Assistant Division Engineer for Civil Works
150 Causeway Street
Boston 14, Massachusetts

Dear Colonel Wachendorf:

Reference is made to your letter of 1 July outlining certain works which are proposed by the Corps of Engineers to protect Stamford against hurricane tidal flooding.

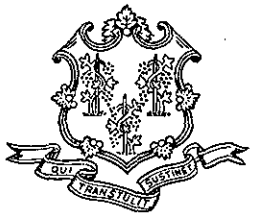
We have gone over this plan carefully and feel that it is not in the least damaging to wildlife resources and, therefore, it has our approval.

Very truly yours,

Lyle M. Thorpe
DIRECTOR

LMT/fc

ABRAHAM RIBICOFF
GOVERNOR



STATE OF CONNECTICUT
EXECUTIVE CHAMBERS
HARTFORD

August 18, 1958

Brigadier General Alden K. Sibley
New England Division Engineer
Corps of Engineers, U. S. Army
150 Causeway Street
Boston 14, Massachusetts

Dear General Sibley:

This will refer to your letter of August 13 requesting opinion concerning the revised report on the hurricane protection project which is proposed for the City of Stamford.

I have consistently supported sound programs for the protection of the people of Connecticut and their development against damages from floods and hurricanes. The City of Stamford has suffered heavy damage from tidal flooding during past hurricanes and protection against the recurrence of such damages is needed.

At the present time there are no specific State funds available for participating in such projects in accordance with the requirements as contained in your letter. However, the executive, legislative and administrative agencies of the State have cooperated and participated in sound projects in the past and now there is no reason to assume that the same policies will not be followed in a sound program for the protection of the City of Stamford when such a project reaches the stage of construction.

Sincerely,

Governor

smv

MAYOR
WEBSTER C. GIVENS

CITY OF STAMFORD, CONNECTICUT

October 28, 1958

Brigadier General Alden E. Sibley
Corps of Engineers, U. S. Army
150 Causeway St
Boston 14, Mass

Dear General Sibley:

At the suggestion of Mr. P. J. A. Scott, of your office, I herewith submit to you my views on the proposed HURRICANE PROTECTION PROJECT for the City of Stamford.

The need for this project is a great one, in my opinion, and is recognized by a large segment of this community. It is my expectation that, should this project receive the necessary Congressional authorization, this City would produce the funds required to pay its share.

The expressed views of members of the Boards concerned with appropriation of such funds give support to this position. At the present time I have no reason to expect any change in this favorable climate of opinion, even if changes in the personnel of said Boards should occur.

I sincerely hope that all administrative and legislative barriers to the commencement of this project will soon be overcome.

Sincerely,

Webster C. Givens
Mayor

WCG/et

FOUNDED 1917

THE NEW YORK TOW BOAT EXCHANGE

17 BATTERY PLACE

NEW YORK 4, N.Y.

WILLIAM E. CLEARY
EXECUTIVE VICE PRESIDENT

WHITEHALL 3-8480

April 14, 1958

Brig. Gen. Alden K. Sibley
Division Engineer, New England Division
U. S. Corps of Engineers
150 Causeway Street
Boston, 14, Massachusetts.

Dear General Sibley:

This communication is with further reference to our telegram dated February 11th, 1958, objecting to proposal contained in your Public Notice of December 30th, 1957, setting forth proposed plans for construction of a hurricane damage control dike across the East Branch of the harbor of Stamford, Connecticut.

As outlined in several conversations with Mr. Peter J.A. Scott and other Members of the hurricane control unit of the New England Division, this entire matter has been the subject of the most painstaking study and review by the Members of the New York Tow Boat Exchange and affiliated marine Associations operating vessels in the East Branch of Stamford Harbor.

Our Members are deeply sensible of the efforts of the Corps of Engineers to bring into being structures which would minimize or eliminate entirely the ravages of hurricanes in coastal harbors and we are eager to cooperate to the fullest extent in those laudable efforts.

However, in attempting to correct one hazardous but admittedly infrequently recurring situation, we are sure that the Corps would not want to create another unreasonable hazard which would have to be faced by navigators of vessels day in and day out.

In requesting in our telegram of February 11th, 1958, that the opening for navigation in either the temporary by-pass or the permanent dike be the full project width of the channel at that point, i.e., one hundred feet, we felt then and still do feel that we were on perfectly tenable ground. When the Corps in its wisdom set the project width of this channel at one hundred feet, full recognition of

the character of the bottom and navigational difficulties were of course taken into consideration by the Corps, and properly so.

Mr. Scott has made us familiar with some of the problems faced by the Corps in revising the plans to conform with our request for a horizontal clearance of one hundred feet and, in the spirit of cooperation, our pilots have reluctantly agreed to permit me to modify the position of the Association to the extent of narrowing the horizontal clearance of the opening in the permanent dike to ninety feet, which is the absolute minimum width necessary for safe navigation.

In towing barges in or out of the East Branch after the dike is constructed, it is the unanimous opinion of our most experienced pilots that the barge would have to be towed "alongside" so as to permit control. Keeping in mind the width of the tug and the width of the barge, plus the intervening fenders between the tug and the barge, it is readily apparent that ninety feet horizontal clearance is the very least that is required for safe navigation.

It is possible that our people might be able to "live with" a little less than ninety feet on the temporary by-pass during the period of construction, but we most earnestly advise you that our request for a width of ninety feet in the opening of the permanent dike represents the absolute minimum so far as the justifiable requirements of navigation are concerned and any reduction in that width would subject navigation to unreasonable, unwarranted and continuing hazards and we are vigorously opposed to the construction of a permanent dike with a navigational opening of less than the ninety feet we have herein set forth.

Yours respectfully,

William E. Cleary

William E. Cleary
Executive Vice President
NEW YORK TOW BOAT EXCHANGE
HARBOR CARRIERS OF THE PORT OF NEW YORK

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Secretary
NEW YORK STATE WATERWAYS ASSOCIATION

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North Atlantic Regional Representative
THE AMERICAN WATERWAYS OPERATORS, INC.